The Institute of Physics

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The Bulletin is published by The Institute of Physics for circulation to its members.

Notices to Members

Oxford Convention

The third Institute Convention, held in Oxford from July 10 to 13, was very successful. A full report, including the text of two of the lectures, will be published in the September *Bulletin.*

Stimulation of Entry to the Profession

The Sub-Committee appointed by the Membership and Examinations Committee to consider ways in which the Institute could help to stimulate entry to the profession has now reported to a special meeting of the main Committee. Its report, which includes several recommendations for positive action by the Institute, is to be submitted to the Board at its meeting in October.

Institute Dinner

An Institute Dinner, which it is hoped will be the first Annual Dinner, is to be held on March 25, 1958, in the Hall of the Goldsmiths' Company, London. Details will be announced later. Members' ladies will be particularly welcome.

Phyisics and Industry Series—New Publication.

The next volume to be published in the Institute's **Physics and Industry** Series is *Pressure Measurements in Vacuum Systems* by Mr. J. H. Leck, which will be issued in early October. Further details, including the special price for members, will be announced in September.

Telephone Number

Members are reminded that the Institute's telephone number has been changed and is now **Belgravia 6111.**

Bulletin of The Institute of Physics

The Origin of Modern Science*

By Professor HERBERT DINGLE, D.Sc.

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THERE are a number of reasons that one could advance for studying the history of science. For instance, it is often said that it is a very useful bridge between science and the humanities ; which is quite true if science is improperly taught ; then the bridge is necessary, but if it is properly taught, then one realizes that science itself is a humanity, so that such a bridge is not necessary.

Again, of course, it has the justification that all history teaching or studying has, that it is something that happened, and if we have normal human curiosity we want to know what it was. That in itself is a liberal education.

But I think that the chief reason, at the present time at any rate, for studying the history of science (and this gets more and more true as time goes on) is that it is absolutely necessary if we are to understand science itself. Science is unique in the respect that, if one reads any scientific paper which is published at the present time, one finds that it has a number of references to previous work, and its validity depends on the validity of the work which is recorded there. Then if one turns up any one of those references, one finds that it has references also, and so one can go back and find that present-day science rests on a steadily growing basis of what has gone before. So unless there is a body of people who are constantly examining the earlier work, any sort of misunderstanding of it gets perpetuated, and the whole of existing science is vitiated. An outstanding example of that occurred when the theory of relativity came in at the beginning of the twentieth century and it was realized that a large part of the work of the nineteenth century had been wasted. All that could have been saved if only people had looked back and understood what Newtonian mechanics was. Instead they built on traditional ideas of it, and then the whole thing had to be scrapped.

This danger gets greater as time goes on, so that it is absolutely necessary that the pushing forward in science now should be accompanied by a study—necessarily by other people, because no one who has to work on the frontiers of science has time to look back—of the great mass of work of the past. Unless there is a body of people who do that, the situation is very perilous. This is becoming more and more realized since the end of the war. It first came prominently to light with the theory of relativity, but since the war an International Union for the History of Science has grown up and is getting stronger every year. The only considerable country that does not take part in it happens to be this country. We must join in sooner or later, of course ; that is inevitable. The need becomes greater and greater, and the longer it is delayed the worse it is.

I have spoken of the series of references going back and back. If one pursues them, one finds that practically everything that is done now rests on work which began in the seventeenth century. There was practically nothing before that that is essential to present-day science. Of course, there is mathematics ; a good deal of early mathematics is necessary ; but that is not science in the strict meaning of the term—it is pure reasoning. It is used in science as a tool. Also, some astronomy was done before the seventeenth century, but none of the early astronomy is essential to present-day science. If it were all lost, we would still have just as firm a basis for present-day science in what has been done since because, owing to the greatly improved methods of measurement, we can now measure changes in a year or so which took centuries to measure before the discovery of the telescope and various other measuring instruments. Anything that was done before the seventeenth century could be ignored without affecting the validity of what is being done now. Therefore, it is important that we should understand clearly what happened in the seventeenth century to give rise to this movement which we now call science.

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* Based on a lecture given to the Education Group of the Institute on January 23, 1957.

One can see the importance of that particular period if one plots very roughly the growth of scientific knowledge against time—although it is not a thing that one can measure precisely, of course. You start from pure ignorance, i.e. a point on the x-axis. Then a great man comes along and makes a contribution to knowledge, and the curve goes vertically upwards a short distance. It continues horizontally until another great man comes along, and then takes another step upwards, and so on. That is how things went more or less until the seventeenth century, and then the curve started to rise smoothly, and has been getting steeper ever since.

It is therefore extremely important that we should understand what happened then, because evidently something quite new came in. People have made out quite an imposing case for work which was done in the Middle Ages as being the precursor of what is known as the " modern scientific method," and of course some particular " scientific " things were done. But those things led to nothing. It was not until the seventeenth century that a *movement* started, which has continued at an accelerated pace ever since.

If we look back at the work of the seventeenth century scientists, the first thing that we notice is that they did not regard themselves as starting some new movement at all, that is, some new kind of subject. They regarded themselves as *philosophers*, and they were always spoken of as philosophers. They thought of themselves as being in the direct line of descent from the early Greek philosophers through the Schoolmen of the Middle Ages. They were doing the same kind of thing ; but they had a different way of going about it. We can see now how different that way was, but of course in those times it did not appear so strikingly unique, because each philosopher regards himself as being the first right philosopher, of course, so that there was nothing peculiar about their thinking that. But the chief point for us to note is that they did not regard themselves as departing from philosophy and starting a new subject called science. They regarded themselves as carrying on the old tradition, but in fact they did it in a new way, and what we have to find out is what were the essential characteristics of that new kind of philosophy which came in at that time. People like Newton, Galileo, Leibniz, Huygens and Descartes would have been surprised, if they could have looked forward a few hundred years, to find that the work of Newton, Galileo and Huygens was to be found only in histories of science and the work of Descartes and Leibniz was to be found only in histories of philosophy. They would not have understood that sharp division, because they corresponded and argued with one another and thought of themselves as doing the same kind of thing. But that is how things have turned out.

If we look back at the history of philosophy before that time, we can classify the various systems in different ways. One of the most significant ways, for our purpose now, is into the empirical philosophies and the rational philosophies, those which were based on experience and those which were based on reason.

In the beginning, of course, philosophy had to be entirely empirical. If you wanted to know what happened, you had to try it. Everything that happened just occurred without any sort of warning—it just rained, or a lion sprang out of the jungle. Whatever happened was just one of those things, and there was no way of predicting it at all. But after a while, when people had got accustomed to that and were learning what they could by mere trial and error, some bright persons noticed that there were certain things which could be foretold without any experience at all. For instance, to take a simple example, if two things happened to be equal to the same thing, then those two things would be equal to one another. One would not need to compare those two things to see whether they were equal to one another or not. It began to be seen that a few things like that could be found out without experience by what we now call pure reason. Naturally, that gave rise to an idea that perhaps everything could be found out in that way, and perhaps one did not need to have any experience at all but could sit down and predict everything that would happen. So the philosophies could be more or less classified into the empirical, based on experience, and the rational, based on reason.

In the Middle Ages and by the seventeenth century, philosophy was almost entirely rational. The aim of philosophers was to devise what they regarded as a rational scheme of things. They laid down certain first principles which were regarded as being guaranteed because they were rational. For instance, the movements of heavenly bodies must be in circles, because the heavens were perfect and the circle was a perfect figure. Again, no decay or change could take place in the heavens ; all change and decay was confined to the earth, or at any rate to the regions below the moon, the nearest of the heavenly bodies. Again, it was taken as a first principle that there could never be a vacuum—nature abhorred a vacuum. If there tended to be a vacuum, something would rush in to fill it. That was regarded as a first principle which one could state merely because it had to be so. It was not a matter of finding this out ; it had to be so because it was rational.

On the basis of first principles of that sort, they deduced a lot of other things. Of course, the outstanding example was Euclid's system of geometry, a very complete system based on a few axioms and postulates which were regarded as self-evidently true. One went on and deduced all the things one could, and it was felt that the material world had to obey those propositions which were deduced.

Those were the predominant philosophies at the time of the seventeenth century. Then a change came. First of all, let us take our own compatriot, Francis Bacon. At one fell swoop he went over to the complete opposite. He saw the barrenness of the rationalist philosophy and became entirely empirical. He said : "Scrap all that and just look round and make experiments and see what happens. Do almost any experiment at all. If you want to study heat, observe anything that has anything to do with heat. Do any sort of experiment and accumulate knowledge, and when you have enough of it and look at it and weigh it up, the truth about heat will more or less fall out by itself." He thought that if people adopted that method, then in a generation or two they would know all that it was possible to know.

It has often been said that Bacon's philosophy was primarily a philosophy for social ends, and that his aim was to gain knowledge for the relief of man's estate—to use his own phrase. It is true that he did foresee that that would happen, but he always put it in the second place. His first purpose was knowledge for its own sake. If you look at any of the passages in which he speaks of the pursuit of knowledge, you find that it is always knowledge for its own sake which is the first thing, and then the application of it to material ends. Both were important, but the first thing was to know what happens. The Royal Society, which was largely inspired by Bacon, was founded on the same principles. If you read its Charter, you will find that that is put in the first place —" to advance the glory of God," as they put it then—and it is evident from the context that they meant praising God for his great works, whatever they might be, and secondly applying them for our own purposes.

Bacon had a very great influence, but his own system (if one can call it a system) led to nothing, and could lead to nothing. But what he did was to release men from what one can call bondage to the traditional pure rationalism, and in that his work was essential.

At the same time, on the Continent, there was Descartes, who was himself a rationalist philosopher, but he had the great merit that he scrapped all those so-called first principles about circular movements, and so on, and made the first thing in his philosophy the doubting of everything one could possibly doubt. If it was possible to question anything, one must question it and not accept it until one had provided a reason for it that one could not possibly question. Descartes made the first principle of his philosophy this absolute doubt. From that he proceeded along a very unfortunate line. He started with his " I think, therefore I am," which is a terrible anti-climax and leads to nothing at all. If you grant that you think, then why bother about the " am "—it does not matter at all. The great merit of Descartes was that he did away with those so-called first principles which had really no justification except that the people who held them liked them.

Then—and this is the most effective for our purpose—there was the work of those whom we still recognize as the early scientists, Kepler and, above all, Galileo. It is chiefly their work that I want to deal with now, because this is what led directly, more than any other thing, to what we now call science.

They found a compromise. The word " compromise " is not perhaps a nice word to use, but they found what we have every right now to think were the right relations of experience and reason. They recognized the value and the limitations of both and set them in their proper relations. One can illustrate that by Kepler's first law of planetary motion, which says that the orbit of a planet is an ellipse with the sun at a focus.

If you observe the movement of a planet, say Mars, for a few months, you will see that while rising and setting with the fixed stars it has also a slow drift among them. It moves, say, at first slowly eastward, then turns back for a while, and then moves eastward again. This process is repeated, giving an eastward path with a succession of loops in it. A pure empiricist would take that to be the actual path of the planet ; it has a motion round and round the Earth once a day, and superimposed on it the other motion which I have described. That would be the motion of Mars according to the purely empirical view. The purely rational view was that the orbit of Mars had to be circular, so the task which the astronomers had for centuries been tackling, not only with regard to Mars but with the other planets also, was to devise the particular combination of circular movements which would result in that sort of appearance. The movements could be in either direction or in any plane, and the planet could move at any speed—all that was allowed—but the path had to be compounded of perfect circles, and it called for quite a bit of geometrical ingenuity to do that. So the whole history of astronomy from almost the first century up to the sixteenth century was a history of the gradual modification and amplification of the particular groups of circular movements which made up the observed movements of the planets.

Kepler made the effective combination of experience and reason. He accepted the observations which gave the positions of the planets without reservation, and at the same time he maintained perfect freedom as to the particular geometrical figure which he would postulate as representing those movements. On the one hand, taking the data by themselves, he was entirely empirical ; on the other hand, in getting the curve which represented them he was entirely rational. One could not by any amount of observation turn an ellipse into a circle, and one could not by any amount of reasoning make the planet move differently from what it did. The two things had their quite definite spheres, and each in its own sphere was infallible. The thing to do was to put them into proper relation to one another.

It is that sort of compromise which is the essence of the new philosophical movement which has become known as science.

That is just an example. The more general aspect of it is embodied in the work of Galileo, and it is Galileo above all who gave us what we can now call the scientific philosophy. Although he did not fully understand what he was doing—it is too much to expect any great innovator to understand fully what he is doing ; none of them has done so, and Galileo was no exception, although he did understand much better than most of his contemporaries—after three hundred years we can naturally understand much better what he was doing than he could himself, because we have seen what has come out of it. I want to describe what he did as it can be seen now, and you must not think that I am trying to describe exactly what Galileo saw.

We can regard what Galileo did as the introduction of three distinct processes—three innovations which have to be taken in a particular order. The first and perhaps most important one can be expressed roughly in this way. Whereas all previous philosophers had regarded the problem as that of describing the nature of the material world—that is, the world of space and time containing material bodies of which one had to discover the nature and their relations with one another—Galileo went beyond that and took as his starting point, not this material world, but our experiences which give us knowledge of it. That is to say, he did not take a piece of chalk, say, as given, but he did take the white colour, the long shape, and so on. Things of that kind were his fundamental data, and from them he had to build up a rational description of the whole of our experience, and not a description of the supposed material world.

I can illustrate that better by generalizing what he did, by going ahead a bit to the way in which we can regard it now, and then coming back to him afterwards.

Let me take two convenient material bodies—first, a lump of sugar. You have there an object and it appears as a cubical outline and a white colour and a hard feeling; if you let it go, it has a downward motion ; it has a sweet taste—and so on. All those things make up, so to speak, the lump of sugar. We regard the piece of sugar as being something outside which generates those experiences in us, but our direct evidence is just of those experiences and we group them together into what we call a lump of sugar.

If you take a child's balloon, you have the same kind of thing, but instead of a cubical outline you have a round shape ; instead of being white, it is perhaps red in colour ; instead of a downward motion, perhaps it has an upward motion when it has hydrogen in it; instead of being heavy, it is light ; instead of having a sweet taste, it has some other taste which I have forgotten !

Those were regarded as two quite distinct material objects, with no relation between them. What Galileo did, in effect, was to break up each of them into separate experiences and regroup the experiences. Instead of grouping the cubical outline of the sugar with the white colour and the sweet taste, he grouped it with the round outline of the balloon and all the other shapes one finds, and considered them as the subject matter of the science of geometry. He took the white colour of the sugar and the red colour of the balloon and considered colours quite irrespective of the object as the subject matter of another science, optics. The downward motion of the sugar and the upward motion of the balloon, and all other motions, became the subject matter of the science of mechanics. You take the various experiences which give you information about these things, and instead of regarding them as being made up into an almost infinite number of groups each containing a few, you have just a few groups each containing an almost infinite number of colours or shapes or motions or sounds. That was the sort of reclassification of the fundamental experiences which Galileo made.

I am going a little ahead of Galileo. What he did was to consider only the motions, but he did abstract the motions from the bodies and consider them by themselves. He looked for laws of motion irrespective of the body which was showing it. Previously the motion had been just one of the properties of the body, like its colour. A body in the sky had to move in a circle. A body on earth had to move in a straight line. If it was predominantly earth or water it moved downwards ; if air or fire it moved upwards—that is, supposing that it was undisturbed ; if it was disturbed it had quite a different kind of motion, a violent motion. Again, a heavy body would fall faster than a light body. The motion varied from body to body. The motion was just a property like the colour. Galileo scrapped all that and took motion by itself, and looked for laws of motion. It was left for later scientists to extend that to things like temperatures, colours and so on ;

but Galileo started that general sort of process, which was the fundamental thing that was necessary in order to start modern science. You regard your data not as a lot of ready-made bodies, but as a lot of experiences which you have, and which you then set about classifying in a way which will lead you most simply and easily to a knowledge of the regularities in them.

The second step was to select the best starting point, so to speak. There was no difficulty in finding motion, with people walking, rain falling, birds flying, rivers flowing—almost everything was showing motion of a kind ; but none of that was of much use to Galileo, because it was too difficult to get any sort of regularity in those motions. So he made an *artificial* motion, and that was the beginning of experiment in the modern sense of the term. He took an inclined plane and made a groove in it, and he took a sphere and let it roll down, and, as you know, he took the distance it moved and measured the time by a water clock. So he got, not very accurately but still quite unmistakably, the very first scientific law of all, that the space covered by a falling body is proportional to the square of the time. That was the first scientific experiment. Of course, there had been experiments of a kind before. The alchemists, for instance, had been experimenting for centuries, but their experiments had been done with a particular end in view—they wanted to turn, say, lead into gold ; accepting lead as it was and gold as it was, they wanted to turn one into the other. They made experiments but always with the one object of turning this thing into that thing. Again, Bacon made experiments, but his experiments were almost entirely indiscriminate—the idea was that one made any sort of experiment that came into one's head ; the individual experiment did not mean anything by itself, but when the whole lot were put together afterwards the truth of the matter would fall out of it somehow. That was a different view of experiment. The experiment as Galileo saw it was the establishing of conditions in which the thing one wanted to study took its simplest form, and that is the type of all modern experiments, as anyone who has done any experiments in a laboratory knows. All the time you are excluding what you do not want so that some simple thing can be left which you can observe. The experiments of Galileo were of that kind. He produced a kind of motion which did show a regularity. The natural ones did not, so he made an artificial one that did. That is now, as you know, an essential feature of modern science. It could not have come before the first step, because you cannot choose a simple example of something you want to study until you have decided that you want to study something. He had to select his right subject for study—motion—and then he had to do the experiment to get the simple type.

The third thing has become so familiar to us that we hardly recognize it at all, and yet it is extremely important. Having got his simple type of motion, Galileo then had to represent it by some kind of concept. A motion itself is just an experience. You see something flashing across, and presumably an animal would see the same sort of thing, but would not represent it conceptually at all. Galileo had to represent that as a concept, and he regarded it as a change of space position with time. That has become so familiar now that we almost regard it as a definition of motion. If somebody asks what motion means, you say that it is a change of position in space as time goes on. But that is not a definition of motion at all ; it is one way in which you can represent it conceptually. At that time it was not even the usual way. The usual way was the Aristotelian way ; it was regarded as a passage from potentiality into actuality. When Aristotle and other people talked about a prime mover, they did not mean motion in the sense that we mean it, but rather in the sense of prime cause—the realizing of potentiality. Of course, nowadays we have quite a large number of other ways of regarding motion. It is true that we always translate them into the space-time terms, but the actual ways in which we represent motions in the first place have very often nothing to do with space and time. For instance, most of the motions in science that we deal with are measured, not by the space covered in a given time, but by the displacement of a spectrum line. That is obtained by just looking through a spectroscope. There are two spectrum lines, the spectrum line from the source in the laboratory and that from a nebula, say. If you see one line, then the nebula is not moving ; if you see two lines, it is. That is putting it crudely, but in principle accurately. You do not observe the nebula over a finite interval of time and measure its change in position in that time. You take one look and see what the separation of the two lines is, if anything. One could, of course, stick to that way ; one need not translate it into space and time ; one could measure the speed by the amount of the displacement, and the direction of motion by the direction of the displacement—one could get the whole characteristics of the motion without bringing in the space and time in which the nebula moved. Again, if you are in a car and it is moving smoothly and the windows are shut, the only way in which you can tell whether you are moving or not is by looking at the speedometer and reading the number at the end of the pointer. If it is 0 you are not moving, and if it is 30 you are. You do not need to measure space or time at all. You need not graduate the scale to give miles an hour ; you can graduate it in any way you like, and that would be a legitimate scale of velocities. Again, you could measure velocities as you measure masses, by weighing them and having a box of " velocity weights," so to speak. A way of doing that was described a good many years ago by Bridgman. If you take a framework of some metal with a wire stretched along, and if you pluck the wire at one end, a wave will travel along it, and the speed of that wave will be perfectly definite. If you make any number of these frameworks according to the same prescription, the speed of the wave will be the same. If you take two of them and let one move so that its *framework* keeps pace with the *wave* on the other (which by definition you call one unit), then the speed of the wave of that would be two units. If you move another so that the framework of that keeps pace with the two-unit wave, the speed of *its* wave will be three units, and so on. In principle, that is just as legitimate a way of measuring velocities as Galileo's. It is a very different way. If you measure speed by the space covered in a given time, you have a finite number for the maximum speed, but if you do it in this way you never reach a maximum—it goes up to infinity. You get a different kind of mechanics if you use that, but it is a perfectly legitimate kind.

I have mentioned these various ways of representing motion, not because I am proposing to substitute any of them for the present one, but in order to show that the present one is a voluntary choice and is not a necessary one. You could represent motion in various ways, and the way which Galileo chose is the one which we adopt now, and it happens to be a most suitable one for this purpose. One can see why he adopted it, because space and time were things that he could *measure*, that is to say, he could apply some process which would represent them by numbers, and that allowed him to use mathematics, which was in his day, as in ours, by far the most highly developed system of reasoning. Since he wanted to form a rational description of his experiences, he needed to make use of the most complete body of reasoning that he had, mathematics; so he represented his motion by something which he could measure and express in mathematical form, instead of by potentiality and actuality, which one could only reason about comparatively vaguely.

Those were the three things which Galileo introduced and which form the basis of modern science. There was, first of all, the substitution of experience itself rather than the world of physical objects as the datum. Secondly, there was the production of artificial examples of the experience, motion, which he was going to study, because of their simplicity. Thirdly, there was the representation of the subject of study in conceptual terms which enabled him to reason about it to the greatest advantage. When that had once been done, then science could start.

I have no time to go over the other branches of science, but very briefly I might show the same thing in the case of heat, That could not be done in Galileo's day because there were no possibilities of accurate measurement. Galileo himself did make an air thermometer, but he did not know anything about pressure of the atmosphere, or at any rate what he needed to have known for this purpose. It was his pupil Torricelli who discovered the facts about the pressure of the atmosphere. It was not until the eighteenth century that thermometers worth calling so were made. The ordinary mercury and glass thermometers with the three standard scales were made roughly at the same time at the beginning of the eighteenth century, and then it was possible to put this program into operation. Those who did so discovered some very curious things. They discovered, for instance, that if one had a number of bodies of different temperatures, as we say—they could not distinguish temperature from heat—and kept them together, then a time would come when they all came to the same temperature. That was a great discovery. In the seventeenth century they used thermometers mainly for measuring patients' temperatures. The doctors used them, and their method was to hold the thermometer bulb in front of a patient, who breathed on it, and the temperature was measured by the rate at which it went up. They did not know that it would reach an equilibrium reading. Another great discovery was that, if one heated some water, a time would come (when it boiled) when the thermometer would not go up any more. That, again, was a great discovery, because previously people had had no idea that there was anything concerned in the matter except just the one thing which they called heat or fire, or matter of heat. They now discovered that they had to distinguish two things. What the thermometer measured could not be heat because it did not record the heat that was going in while the water was boiling ; so they had to separate heat from temperature. Those two ideas play the same kind of part in the science of heat as space and time play in the science of mechanics. They are concepts in terms of which one represents the experiences that one has. Then, of course, later on entropy was added. So it went on, and ultimately you arrive at the laws of thermodynamics, which get away from material bodies altogether ; they just describe the relations between heat, temperature and entropy irrespective of any particular bodies that show them, just as the laws of mechanics show the relation between mass, space and time irrespective of any particular bodies which happen to show them.

That is a very rough sketch of how it was done, and the same thing is true in other sciences.

Now, regarding this as a new kind of philosophy, what sort of philosophy can we call it ? Of course, gradually, but not immediately, it got separated from philosophy and was called by a different name—science. It would be interesting to trace (it has never been properly done) the history of the division between what we call science and philosophy. The *Philosophical Magazine* is entirely a scientific journal now, and always has been. It started publication at the end of the eighteenth century, but recently, I believe, it was decided, because of lack of space, not to publish philosophical articles in it, but it is still the *Philosophical Magazine.* Faraday regarded himself as a philosopher, and it was so until well on into the nineteenth century. When Keats in his poem talked of all charms flying at the mere touch of cold philosophy, he meant not philosophy but science.

This gradual separation of science and philosophy, which in our day has come to almost a complete division between them, is unfortunate in many ways. For one reason, it allows people who are still called philosophers to go on with their ineffective methods under a dignified title. However, there it is.

To see what kind of philosophy this is, we must take another traditional division of philosophies, namely the division into idealistic and realistic philosophies. Those names are both made to cover a multitude of sins, so one has to explain what one means by them. Briefly, the meaning I imply now is indicated by this question. If I say, for instance, " There is a piece of chalk," is the primary thing there the existence of the chalk and my experience of it a secondary thing ? Do I just happen to experience it because I am here to see it, while if no one experienced it, the chalk would be here just the same ? A positive answer to this question would be a *realistic* one. The *idealistic* answer would be to say that the first thing is the experience, and that it is because of that experience that we are justified in saying there is a piece of chalk there ; if no one saw it or had those experiences, there would be no justification for saying it was there. So if you are going to be rational and argue from evidence to conclusion, you have got to take your experience as the primary thing and the existence of the material object as a deduction from that. It might be a right deduction or a wrong deduction, and it might be neither one nor the other, but a voluntary one—but at any rate it is a secondary thing ; it is a deduction from what you experience. That is the idealistic view.

Taking those meanings of the words, there is no doubt what kind of philosophy science is. It is idealistic because it starts from experience. It does not start with a material object, it starts from the experiences, and in fact it does not recognize a material object as such at all, but makes laws of motion, optics, and so on, and not laws of chalk, glass, and so on. So it is essentially an idealistic philosophy.

What are the consequences of this kind of philosophy ? In the first place, if you start from experience and not from the material world as given, then you cannot draw a hard-and-fast line between one kind of experience and another as you could beforehand. For instance, if you take the material world as given, you could say that my sight of a white colour there in front of me is a legitimate thing to study, for it is a legitimate experience, but the dream I had last night is not, because the dream was not real, it was just imaginary. But if you start with experience, then they are both experiences, my sight of the white colour and my dream. Both of them are equally experiences, and so one is no more fit for scientific study than the other. In fact, with the progress of science that has come to be recognized, and in scientific psychology, dreams are as important as anything else—and so are the illusions that we usually have. If anyone thinks that illusions are not important, then just tell him about Hitler ! They are just as important as bits of chalk. The reason why we could previously make that distinction between what we call real experiences and illusory experiences is that the real ones are much easier to deal with ; you can find regularities in them much more easily than in the others; so we started with those. But the time will come, no doubt, when we shall have just as sound and legitimate a science for dreams as for colours. That is inherent in the view that you start from experience. It is inherent in that view that, potentially at any rate, any experience at all is a fit subject matter for scientific study, and the reason why some have advanced much farther than the others is that they are much easier to deal with.

Then, another essential distinction between this scientific philosophy and the previous philosophy is that this is a gradual process, whereas the previous philosophers tried to do everything at once. They had complete systems ranging from trivial things like the rolling of a piece of chalk up to the immortality of the soul and the existence of God. All were included in the same philosophy. The scientific philosophy scrapped that ambition entirely; it said: "Let us sacrifice importance for certainty ; let us start with the things we can be, if not absolutely sure of, at any rate as sure as we can be of anything. They are utterly trivial things, like rolling balls down slopes and so on ; they are of no importance in themselves, but by studying those we can get simple laws on which we can build and go on to other things, until in time, many generations ahead, people will be able to approach the big problems and find solutions for them which are utterly out of reach now. We shall never reach the really valuable and complete solutions unless we give up the ambition to do it all ourselves, and just start with simple things and let our successors build on that and reach the ultimate things later."

Of course, this means that in any particular generation one has to do two things. If you are really interested in these fundamental things, then you cannot treat them scientifically, because the time is not ripe for that, but you can recognize that science is potentially able to deal with them and at the same time adopt a practical working philosophy in thinking of things like aesthetics, religion and so on. So when people ask whether these things can be dealt with scientifically, the question is rather ambiguous. At present they cannot be dealt with scientifically, because the scientific way is now to deal with things which we can manage and not with things which we cannot. On the other hand, if the meaning of the question is whether potentially they can be treated scientifically, the answer is, yes, they can, or at any rate there is no reason to suppose they cannot be, because since we have succeeded so far as we have with the simple experiences, there seems no reason why in time we should not be able to comprehend all experience in a rational system. At any rate, I for one would not like to think that experiences of that kind are entirely capricious and cannot be brought within a rational scheme. I cannot do it myself, but I believe that some time people will.

There are many aspects of this subject, but I have time to mention only one other. We often talk of " scientific method," and I think the phrase is usually used quite wrongly. There is a sense in which you can speak of scientific method. If you first of all think of science as philosophy, then you can regard science as the particular method of philosophy which I have been trying to describe. But what is often intended to be implied by the phrase " scientific method " is that it is a sort of way of doing things which can be carried over from what we call science into politics or anything else you like. We talk of " doing things scientifically " as if " scientifically " were one among a number of other ways of doing things. That is utterly wrong and gives rise to a very large number of illusions.

To take an example, suppose you are dealing with a certain problem. Suppose you want to synthesize a particular organic substance in the laboratory which has never been synthesized yet. You say, " All right, I will go about this scientifically." So you get a book on scientific method—you get any one you like, for there are a large number of them, though they do not all agree. You read it all up, and you set about the job " in a scientific way," and you do not succeed at all. Then one night you happen to dream that you are in the laboratory and you mix together the most unlikely things and, lo, the thing comes out. So the next day, for fun, you do it and see what happens—and you find that it does come out. It is the second one that becomes science, and not the first. The first one is conducted by scientific method, but does not lead anywhere ; the second is just done any way, and it leads somewhere, and the moment it does lead somewhere it is science. You find in the history of science that things have been found out in that way—by dreams. And, of course, there are a number of examples of Newton's falling apple type. In fact, I will not say there are not any, but it would take you a long time and much searching in libraries to find any scientific discovery that has been made by any of the methods given in books on scientific method. So if you hear the phrase " scientific method " used as describing a way of doing things, you can be quite sure that it is entirely wrong. The only legitimate meaning for " scientific method " is when you think of science as philosophy ; then it is this method of philosophy—the gradual method, proceeding in the way I have described—which was started in the seventeenth century.

One could talk about a number of things under this heading, but my time is up, so I will stop there.

Reviews of Books

ELECTRICITY AND MAGNETISM

By B. I. Bleaney and B. Bleaney

London : Oxford University Press. Pp. 676 + xiv. Price 63s.

The first two-thirds of this book are concerned mainly with the macroscopic or field approach to electrical theory, and the remainder with the atomistic or electronic approach. However, the authors have not hesitated to use atomic and electronic ideas in developing the field theory, when it seemed appropriate. The first eight chapters deal with electrostatics, direct currents, conduction in metals, liquids and gases, magnetic effects of currents and charges, electromagnetic induction and varying currents, d.c. measurements and magnetic materials and measurements. There follow three chapters on a.c. theory, electromagnetic waves and transmission circuits including filters, lines and waveguides. After a chapter on generators, motors and transformers there are three chapters on electronics covering valves, amplifiers, oscillators and some of their applications. One of these chapters deals with valves for very high frequencies. A chapter on a.c. measurements concludes the macroscopic section. The atomistic section is introduced with a chapter on fluctuations and noise, and proceeds through dielectrics and solid state conduction to three chapters on atomic theories of magnetism. The final chapter is on units.

The book is remarkable for its omissions as well as its inclusions. For example, there are about a hundred pages on atomic theories of magnetism including ten on nuclear magnetic resonance, yet the subject of terrestrial magnetism is covered in two and a half pages. The authors are to be congratulated on making a welcome break away from the traditional physics text book. The basic principles are covered adequately and clearly, and the sections on measurements, transmission, electronics and solid state phenomena are, on the whole, dealt with admirably and sensibly. The use throughout of m.k.s. units is an interesting and welcome comment on the units controversy. Vector methods are used from the beginning and there is the inevitable appendix on vector analysis.

Some teachers may not agree with the choice of applied material or of the more specialized advanced topics, but these are largely matters of individual preference. On points of detail, it is rather surprising to find crystal diodes and transistors described qualitatively under valves, with no attempt to relate them to the semiconductors dealt with later in the book. Though p- and n- type semiconductors are introduced there is no explanation of the rectifying properties of a p-n junction. The section on power amplifiers is an extraordinary and inconsistent mixture of empiricism and small signal theory. The bare statement that the g_m of a valve is limited by cathode emission is somewhat misleading.

In spite of minor criticisms, this book is thoroughly recommended as a valuable contribution towards more enlightened treatment of electricity and magnetism in honours schools of physics, in universities and advanced colleges of technology. It is well produced with numerous clear diagrams, and at present prices it represents good value.

M. R. GAVIN.

AN INTRODUCTION TO REACTOR PHYSICS

By D. J. Littler and J. F. Raffle

London : Pergamon Press. Pp. 208 + x. Price 30s. Second Edition

This book, published for the United Kingdom Atomic Energy Authority, contains the substance of lectures given in the Reactor School at Harwell to physicists and engineers concerned with the design and construction of reactors for the nuclear power programme.

The text falls naturally into three parts. The first four chapters provide a concise account of atomic and nuclear structure, radioactivity and fission. The next eight chapters, constituting about half of the book, describe the principles underlying the design and operation of gas-cooled reactors with natural uranium fuel and graphite moderator, as built at Calder Hall and elsewhere. Three concluding chapters deal briefly with reactor shielding, radiation detectors and radiation damage to materials.

The reader should have a modest degree of skill in elementary mathematics, including a familiarity with ordinary differential equations, but no previous knowledge of nuclear physics is assumed. The book is written in a pleasantly didactic style, with an abundance of numerical illustrations and helpful simple diagrams ; the text reads very much like a good set of lecture notes.

Incidentally to its main purpose, this book offers many attractive illustrations of physical principles and mathematical techniques. It may, therefore, be interesting to those responsible for the teaching of honours students in physics and engineering.

J. M. A. Lenihan.

PHYSICS

By S. G. Starling and A. J. Woodall

London : Longmans, Green and Co. Ltd. Pp. 1328. Price 55s. Second Edition.

This textbook was extensively reviewed and was deservedly well received when it was first published in 1950. Since then it has passed through two additional impressions, in 1952 and 1955 respectively, when only minor corrections were made to the original text. Its popularity has in no way declined and it should continue to be in great demand, although its price has increased. As far as the reviewer is aware it still remains the only one-volume textbook, covering all branches of physics, of a standard suitable for undergraduates of British universities, particularly those students reading for a pass or general degree or studying physics as an ancillary subject in a special honours course. The new edition is not significantly different from the earlier edition. The titles, lengths and subject matter of the 53 chapters remain virtually unchanged. A short section on rotatory motion has been inserted in Chapter 2 and the treatment of alternating currents in Chapter 47 has been improved though the authors still prefer to use capacity instead of capacitance. The illustrations and line drawings are, except for one or two minor instances, identical with those of the first edition. The main change is that to an already much too lengthy and weighty tome the authors have seen fit to add four appendices, amounting it is true to only sixteen additional pages, but which do not serve any very useful purpose. They deal with vacuum physics, electronic apparatus, the m.k.s. system of units, and suggestions for further reading. The small amount of important additional material they provide could have quite easily been incorporated in the main text. The increase in the number of examination questions and exercises at the end of the book is, however, welcome. It is suggested that for the third edition the main text be carefully examined and pruned, and that the mathematical and physical tables be omitted if necessary, in order to make this valuable textbook more compact, yet able to keep up with the rapidly expanding content of physics.

S. Weintroub.

MAN AND MATERIALISM

By Fred Hoyle

London : George Allen & Unwin. Pp. 161. Price 12s. 6d.

This book, which is sufficiently concise and interesting to be read at a sitting, leaves the reader rather in the mood which used to be induced by the first hearing of a play by George Bernard Shaw. Something has happened, much has been said, and it would be better to take a strong drink before going to bed to check the continued spinning of one's mental processes.

On the next day one is less certain of what has really happened—some of the audience have acquired a few new slogans and a smaller number will have a few new ideas. If a book can do as much as this it is worth reading.

Materialism is, to quote the preamble, a refusal to separate man and his environment into the mutually exclusive categories of " spiritual " and " material " ; and the author is to be congratulated so far as he helps readers to arrive at a more closely reasoned and closely integrated picture of man and his relationship to the universe. Three of the earlier chapters of the book deal with Communism, Evolution and Industrialism, in that order ; they are lucidly thought out and would be acceptable to most people of the Fabian Society and *Manchester Guardian* type. The order in which they occur may be confirmatory evidence of the author's subsidiary point of view mentioned in the preamble, that " no attempt is made to introduce the notions of value or importance."

In the chapter on Industrialism the author clearly states the purely rational case against war, with such coolness that one could safely give this book to a young soldier without risking prosecution, even in wartime.

After these chapters, the author introduces the idea of " The Thing "—the superstructure of human society which appears in some way to control the destiny of the human species ; and which is associated with mankind in some such way as the activities of mind are associated with a brain. This is followed by a chapter discussing " What is the Mind ? " and one on the relationship of the individual and community. These chapters are clear and helpful attempts to describe objectively some of those aspects of our behaviour which we usually fail to see clearly because we cannot detach ourselves sufficiently to get them in perspective.

At this point the author returns to the evolution of humanity, not only as history, but as a continuing process, and here he relates it to " The Thing " in a way which enlarges and enriches old-fashioned materialism until a Christian begins to suspect that God is creeping in anonymously. If not God Himself, then Hermes Trismegistus (or the Egyptian Thoth), god of mathematics and science, whose function it was to summarize and inspire the principles of change in nature. This would fit in with the author's phrases :—" evolution takes place in such a way that The Thing extends its scope and its power. The human individual does not progress except in so far as he is a component of The Thing."

This seems to the reviewer to be equivalent to attaching some idea of value or importance to " The Thing," as perhaps we may suspect was intended by the author, who dignifies this idea as well as those of God, Man, Communism and Capitalism with capital letters—so did Shaw, except for Man !

The last chapter of the book deals, hardly successfully, with the religious impulse in man. The author is too honest to deny that such an impulse exists, but he so misunderstands its nature as to state that " religion, if it is not to be pernicious nonsense, must be based on rational thinking." Readers who are fortunate enough to have a religion based on their inner experiences will see the point, others may agree with the author. But this is not all ; the author goes on to say that the religious impulse is involved in the propounding of questions of purpose, questions such as " where does the ultimate purpose, or aim, of the human species lie ? " and in attempting to answer them. Admitting that there is no simple answer to this question, he encourages us to look toward the closer identification of man and the universe for part of the answer, and he goes on to identify the most characteristically human aspects of man with the extreme complexity of his organization.

The author suggests an experiment which cannot yet be performed—the making of a careful record of all the atoms in a human being and their relationships. If later someone were able to assemble a corresponding set of atoms, in their proper relationship, an identical human being would result, and would appear alive. He admits that this would be a surprising result, and that at present for technical reasons we could not carry out this experiment successfully, but maintains that in principle it could be done.

Readers who suspect that the result of the experiment would only be a corpse would, the reviewer supposes, be told that they did not read the definition of the experiment carefully ; it is assumed that the atoms could be re-arranged in a similar way to their previous relationships, and if this is understood dynamically " resurrection can be placed on a logical footing." If this is true, then perhaps it is less surprising to be told in one of the last paragraphs of the book that " The universe revealed by painstaking scientific investigation is so incomparably grander than anything that the ' men of faith ' have ever told us about."

In conclusion, the book is a clear and honest attempt to look at man and the universe and describe them, in their relationship, objectively. This view is rather dull, compared with the view of man's place in the universe seen by St. Francis of Assisi.

Ernest van Someren.

BRITISH PHILOSOPHY IN THE MID-CENTURY

Edited by C. A. Mace

London : George Allen & Unwin. Pp. 396. Price 30s.

This book consists of a series of lectures delivered at Peterhouse, Cambridge, in the summer of 1953, under the auspices of the British Council. Evidently, it represents something much more substantial than yet one further " get-together " of a posse of specialists. In fact, this collection of distinguished essays presents British philosophy as it is at approximately half-time in the twentieth century. As one would expect, the names of the contributors (by no means all Cambridge celebrities) include most of those well qualified for their task, and no easy one it must have been.

All of which prompts the obvious question: what has all this to do with physics ? And oddly enough, the answer is not explicitly given—there is no reason why it should be—by any one of these savants, but by a philosopher of a past generation, the late Lord Haldane. He opined that the purpose of education was not the acquisition of knowledge, vital as that is, but the conscious inculation of a sense of values. Probably most people would admit this in one form or another as applied to formal learning ; what we have here is the principle standing out as a warning against a surfeit of facts, and facts alone, whether in honours examinations, or in applied physics run riot. Professor Broad supplies perhaps the best comment on this. He notes that of all the approaches to philosphy in Cambridge during the period under review, the most rewarding have been those made by the mathematicians, e.g. Whitehead and Russell. These have been more productive than the efforts of the biologists and social scientists in corresponding fields. This, of course, is not to say that such subjects will always come in second, but it does indicate that the exact sciences, especially physics, have much to give, and to receive, at the hands of the philosphers.

Another point is that the dichotomy which exists at Cambridge between the study of the ancient and the modern philosophies is paradoxical. The " history " begins with Descartes, whereas it is the classical scholars who know all about Greek philosophy, with its deep implications for natural science.

Perhaps it is largely irrelevant to the physicist who it is who teaches this or that ; there can be no doubt at all that this volume should be a stimulus to scan as widely as possible the entire screen of human concepts, in the belief that only by so doing can a natural philosopher—i.e. a physicist—become of full stature, and ready to advance the frontiers of knowledge not merely because it pays, but because it possesses axiological import.

F. I. G. Rawlins.

The Graduateship Examination, 1957

The Institute's Graduateship Examination was held on June 3–7. Written papers were taken in London (The Polytechnic, Regent Street), Birmingham (College of Technology), Salford (Royal Technical College), Paisley (Technical College), Swansea (Technical College) and a practical examination was held in London (The Polytechnic, Regent Street) and Salford (Royal Technical College).

Sixty-eight candidates took papers other than the General paper. Twenty-one satisfied the examiners in all the papers they were required to take. The successful candidates were the following, the colleges at which they studied being given in brackets.

A. B. Denham — Dartford
(*South-East London Technical College*)
J. France — Chester
(*Liverpool College of Technology*)
R A. E. Fursey — Hounslow
(*Acton Technical College*)
M. S. Gates — Farnborough
(*Guildford Technical College*)
J. Henderson — Glasgow
(*University of Glasgow and Royal College of Science and Technology, Glasgow*)
D. R. Hill — Enfield
(*Northampton Polytechnic, London*)
P. R. Hillier — Calcot
(*Northampton Polytechnic, London*)
R. C. G. Lewis — London
(*South-East London Technical College*)
R. Murgatroyd — Wigan
(*Wigan Technical College and Royal Technical College, Salford*)
R. L. Otlet — Didcot
(*Oxford College of Technology*)
A. Packwood — Porthcawl
(*Glamorgan Technical College*)
R. Payne — Sutton Coldfield
(*College of Technology, Birmingham*)
H. B. Renny — London
(*Northampton Polytechnic, London*)
E. A. Ryder — Wembley Park
(*Bristol University*)
H. C. Sanson — Harwell
(*Oxford College of Technology*)
T. H. Storr — Newbury
(*Oxford College of Technology*)
R. W. Suhr — Birmingham
(*College of Technology, Birmingham*)
L. F. W. Thomas — Dartford
(*South-East London Technical College*)
K. D. Warrilow — Basingstoke
(*Northampton Polytechnic, London*)
J. M. Welland — Reading
(*Northampton Polytechnic, London*)
A. S. Younger — Aberporth
(*Swansea Technical College*)

The performance of A. B. Denham was considered to be specially meritorious ; the examiners have decided that he shall be eligible to apply eventually for Associateship of the Institute on the basis of the shorter period of experience required of graduates with high honours.

As is shown by the following table, most of the candidates held qualifications giving them partial exemption.

	Candidates	*Passed*
Holders of degrees	18	5
Holders of the Higher National Certificate in Applied Physics	45	14
Others	5	2
	68	21

Only two candidates took the General paper this year, and both of them satisfied the examiner ; they are now held to satisfy the Institute's requirements of General Education.

The results in each paper were :—

	No. of Candidates	*Passes*
Physics I (General Physics and Acoustics) ...	49	15
Physics II (Heat and Optics)	44	25
Physics III (Electricity and Magnetism) ...	7	3

Mathematics I	5	2
Mathematics II	5	2
More Advanced Physics...	20	5
Electronics	13	9
Statistics	3	1
X-rays	2	2
Spectroscopy	2	1
Mathematical Physics ...	2	1
Practical examination ...	12	11
General Paper	2	2

The papers set are reprinted here. Papers in Applied Optics and Applied Acoustics are included although the candidates who entered for these papers withdrew before the examination. The comments of the examiners on the performance of candidates are published after the papers.

Papers set in the Graduateship Examination, 1957

PURE PHYSICS I — GENERAL PHYSICS AND ACOUSTICS

Examiner : Professor J. G. Wilson, M.A., Ph.D., F.Inst.P.

MONDAY, 3rd June—9.30 a.m. to 12.30 p.m.

(*Answer* FIVE *questions, at least* THREE *from Section A*)

Section A

1. Define the principal moduli of elasticity of an elastic solid, and show how limits may be set to the value of Poisson's ratio for an isotropic solid.

What interpretation would you place on departures from these limits in experimental work on actual specimens ?

2. Discuss the principles which govern the isolation of vibration-sensitive laboratory instruments from the transmitted disturbances of a building. Describe a particular application of these principles.

3. Derive an expression for the Maxwell-Boltzmann distribution of velocities in a gas consisting of molecules of a single kind, and for the root-mean-square velocity of these molecules.

Evaluate the r.m.s. velocity of hydrogen for the conditions of the terrestrial atmosphere, and suggest whether or not hydrogen in the atmosphere will tend to escape from the earth.

4. In the Carmichael quartz fibre electrometer the fibre was hung from one end while the other end, the deflection of which was observed, was free. Discuss the way in which the Brownian movement of the fibre and the viscous damping of its motion by the surrounding gas would depend upon the gas pressure, and indicate the bearing of these quantities on the practical limit of sensitivity of the instrument.

5. What do you understand by the Fourier analysis of a wave form ? Discuss the practical importance of this analysis, considering, among other features, any condition in a real physical system which may limit the relevance of Fourier analysis.

6. State Newton's Law of Gravitation.

Assuming the earth to consist of a core of radius one half that of the earth and of density $10\,\text{g.cm}^{-3}$ surrounded by a mantle of density $4\,\text{g.cm}^{-3}$, how would the period of a simple pendulum change when it is taken down a deep mine ?

Section B

7. The compressions and rarefactions taking place in the propagation of sound waves in a gas are treated as adiabatic. Upon what evidence do you believe this assumption to be correct ?

Indicate in outline how you would proceed to check theoretically that it is a suitable assumption, and point out the conditions under which it may be in danger of failing.

8. Describe the operation of the various sections of the human ear which are relevant to the transmission of sound vibrations up to the stage at which signals pass into a nerve system.

Give a short account of the sensitivity of the ear for pitch and for loudness.

9. Explain the difficulties in securing high-quality reproduction of sound (for example, orchestral music) in a normal small living room. You may assume that a suitable electrical system feeding to the output acoustical device has been attained.

PURE PHYSICS II — HEAT AND OPTICS

Examiner : PROFESSOR H. LIPSON, M.A., D.SC., F.INST.P., F.R.S.

MONDAY, 3rd June—2.00 p.m. to 5.00 p.m.

(*Answer* FIVE *questions, at least* TWO *from each section*)

SECTION A

1. Write a brief essay on the measurement of temperature.

2. Explain clearly the meaning of the Van der Waals' equation

$$\left(p+\frac{a}{v^2}\right)\left(v-b\right)=RT$$

How can this equation be said to represent the change from gas to liquid ?

Explain how the critical isothermal of a gas can be derived from this equation and show that a general equation of state results if the temperature, pressure and volume are measured in terms of the critical values.

3. A fuel rod in a nuclear reactor has radius a and conductivity K_1 ; it is surrounded by a thin sheath of thickness b and conductivity K_2. If the rod produces Q calories per c.c. per sec., what is the difference in temperature between the axis and the surface when a steady state is reached ?

Suggest a way in which the result could be tested experimentally with some device for simulating the nuclear production of heat.

4. Define enthalpy and explain its importance in thermodynamics. Explain what is meant by the Joule-Kelvin effect, as demonstrated in the porous-plug experiment, and discuss its application to the liquefaction of gases.

5. What is black-body radiation ?

Explain how you would determine the distribution of energy in the spectrum of black-body radiation. Discuss results that have been obtained, and show how they led to the introduction of the quantum theory.

SECTION B

6. What is spherical aberration ?

A plano-convex lens is made of glass of refractive index 1·50, and has a radius of curvature of 20 cm, a thickness at the centre of 3 cm, and a diameter of 10 cm. Find the variation in focal length when (*a*) the curved surface, (*b*) the plane surface, faces the incident light. Discuss the practical significance of the result.

7. Describe the phenomenon of double refraction in crystals and explain briefly its origin. What would be observed if a beam of unpolarized light were passed through two similar and similarly oriented doubly refracting crystals, one of which is then rotated slowly about the direction of the incident beam ?

Discuss the application of the principles of double refraction to the measurement of stress in a transparent body.

8. A lens of variable aperture is used to form a real image of a diffraction grating illuminated by a beam of coherent light parallel to the axis of the lens. Describe and explain the nature of the image when the lens admits (*a*) the zero order of diffraction only, (*b*) the zero order and the two first orders, (*c*) several orders.

Describe also what would be observed if the incident light made a finite angle with the axis.

Discuss the implications of these effects upon the theory of image formation in general.

9. Write a brief account of the measurement and specification of colour.

MORE ADVANCED PHYSICS

Examiner : PROFESSOR H. LIPSON, M.A., D.SC., F.INST.P., F.R.S.

TUESDAY, 4th June—9.30 a.m. to 12.30 p.m.

(*Answer* FOUR *questions*)

1. What are the differences between the diffraction of X-rays, electrons and neutrons by atoms ? Explain why the diffraction of X-rays and electrons depends upon atomic number, why the intensity of the diffracted beam falls off with angle of scattering, and why the fall-off is more gradual the higher the atomic number.

Explain Bragg's suggestion that a beam of X-rays diffracted by a crystal can be regarded as reflected from a set of lattice planes. Thence derive Bragg's equation giving the possible angles of diffraction by a set of lattice planes, and outline its application to the determination of a simple structure such as that of rock salt.

2. Explain what is meant by diamagnetism, paramagnetism and ferromagnetism.

Explain briefly what conditions must be satisfied in order that an element may be ferromagnetic and thence explain why it is possible to produce a ferromagnetic alloy containing no iron, nickel or cobalt.

Describe and explain a method for measuring the susceptibility of a ferromagnetic element up to and above the Curie point, explaining how the value of the Curie point is accurately obtained.

3. What is meant by multiple-beam interference ?

Why is a multiple-beam interference pattern much sharper than a double-beam interference pattern ?

Describe a method of obtaining multiple-beam interference patterns, and discuss their use for examining the fine detail of surface topography of a specimen. Discuss the limitation on the detail that can be so observed.

4. What is meant by (*a*) the four quantum numbers of the orbit of an electron in an atom, (*b*) Pauli's exclusion principle ? Explain the bearing of these concepts on the behaviour of electrons in metals, and discuss the effect of this behaviour upon electrical conductivity.

5. Describe an apparatus with which the photoelectric effect in pure metals has been investigated quantitatively.

Explain how the effect is found to depend upon (*a*) the intensity, (*b*) the wavelength of the incident light, and show how the results provide confirmation of the quantum theory.

Describe the construction and theory of operation of the barrier-layer photocell.

6. (*a*) Describe briefly Millikan's method of measuring the charge on the electron.
   (*b*) Discuss the principles of the measurement of the wavelengths of X-rays by ruled gratings.

Explain why these two measurements are related ; discuss the inconsistency that was found when the experiments (*b*) were originally carried out, and explain how the inconsistency was removed by a re-determination of the viscosity of air.

7. Explain the considerations that led to the supposition that moving particles should possess wave-like properties. Describe how this supposition was tested experimentally for moving electrons, and discuss the bearing of these experiments upon microscopy.

GENERAL PAPER

Examiner : N. CLARKE, B.SC., F.INST.P.

TUESDAY, 4th June—9.30 a.m. to 12.30 p.m.

(*Answer Questions* ONE *and* TWO *and any* THREE *others*)

1. (*a*) Express the substance of the following passage in your own words :

" Since the paper was critical, independent, and in frequent opposition to popular opinion, he felt that everything should be done to make it clear to the average man and woman. It was to appeal to the intelligent rather than to the erudite. He tried to keep out of it the pedantic and obscure, pretence and ostentation. He liked plain English, holding that everything in a foreign language, living or dead, that crept into the paper could have been said as well or better in English (' Why do they say " portfolio," when they mean an English "Ministry " ? '). He constantly asked the question, ' What does he mean ? ' If a man who had allowed something unintelligible to appear in the paper said ' I thought it meant so-and-so,' ' C.P.' would forgive the greatest stupidity, but to insert anything without having a clear opinion, however wrong, about its meaning, was a serious offence. ' But, my dear fellow, if you didn't think you knew what it meant, you shouldn't have let it in.' He would go bustling into a room, waving a cutting or a proof, in which was an obscure phrase, a preciosity or an Americanism. ' What does he mean by this ? He talks about a " final showdown ? " An Americanism, I suppose. What does it mean ? Generally known ? . . . I don't know it. Taken from cards ? I never heard of it.' He resented, except in a few cases, the use of initials, especially in headlines, to represent some body with which the journalist might be familiar and the public not. He carried this objection far. For a long time after the railway amalgamations he would not allow L.M.S. to appear in a headline. He had found it at the top of a Short Leader. He came in, according to his custom, bristling. ' These letters L.M.S.' he said ' What do they mean ? ' The amalgamations were recalled to him. ' May be,' he said, ' but what do the etters stand for ?' 'A combination, Mr. Scott, of the London North-Western . . .' 'Ah,' he said, relaxing, 'That explains it. I always went North-Western and I can never think of it by any other name.' What was intended to be intelligible to the public, in a leader, a report, a telegram, or a poster, must be intelligible to him, an admirable standard of measure since he never pretended to be a know-all but was unsurpassed in clear thinking and expression.

The slovenliness in language which, partly because of loose thinking, partly because of mere misuse of words, threatens to infest a newspaper, roused him. 'Look at this,' he said. 'Blank died literally in harness. He didn't.' Or, 'This man says that we shall have to pay literally through the nose. He knows we shan't.' He protested almost passionately against a witness at an inquest who described himself as having been 'only too willing' to save a woman from drowning. 'He doesn't mean that, you know' said 'C.P.' 'Then why does he say it ?' He watched for and cut out of the paper false usages and vulgarisms. He sent the cutting sometimes to the culprit, more often to one of his assistants for what he called the 'little collection.' He would not allow misuses in reports and contributions to be justified by the distinction of either Cabinet rank or a University Chair. Drawing attention to a lapse by a well-known master of letters, he said, 'Even the great can stumble—but it should have been altered.' He demanded a certain precision and dignity of language ; all parts of the paper, reports and letters to editor included, had to conform to it. He was fastidious about translations, especially from the French, a language to which he gave exact attention. He was impatient with writers of letters who complained when English grammar was forcibly imposed on them. 'They ought to be grateful to us,' he said, 'as speakers should be to reporters.' His vigilance extended to the smallest points. If Mr. Lloyd George was 'Mr. George' in the leader-columns, that was the precision of 'C.P.' not, as Mr. George is reported to have said, the malice of Labour men gathered on the Guardian staff."

W. P. CROZIER
contributed to *C. P. Scott*
(by J. L. HAMMOND)

(*b*) Give meanings, in the context of this passage, for—***erudite, pedantic, ostentation, infest, literally, fastidious, vigilance.***

(*c*) What are the objections to *Blank died literally in harness* and *only too willing* . . . ?

2. Write an essay on one of the following subjects—

The International Geophysical Year
The first Lord Baden-Powell
Scienceand warfare
Human relations in industry
" Rock and Roll "

3. Discuss the influence of American films, magazines and television programmes on modern English life. Do you approve of the effects of these influences ?

4. What kind of job would you like to be doing ten years from now ?

Describe the sort of duties that you think would be involved, and the reasons for your choice. Are you likely to have that job ? Why do you think so—or not ?

5. Why do you think that so many people wish to emigrate from this country to Canada and elsewhere ? Do you think it desirable that people should wish to go ? Would you like to emigrate ? Give reasons.

6. Discuss the hazards involved in " tests " of nuclear weapons.

7. Which author do you most enjoy ? Discuss some of his or her best known work and indicate why it appeals to you.

STATISTICS

Examiner : E. D. van Rest, M.A., B.Sc., F.Inst.P.

TUESDAY, 4th June—2 p.m. to 5 p.m.

(*Candidates should attempt not more than* FOUR *questions of which at least* ONE *should be chosen from the first three*)

1. Three pieces of conducting material of the same and uniform cross section, 5, 8 and 15 cms long respectively are balanced by a bridge method against lengths of copper wire, also of uniform cross section, with the results given below.

5 cms length equivalent to	8·75	9·31	9·01	8·81	cms copper
8 „ „ „ „	10·41	10·83	10·52	10·24	„ „
15 „ „ „ „	14·24	14·12	14·18	13·98	„ „

On the assumption of simple proportionality between increase of resistance and increase of length, estimate the contact resistance under the conditions of this experiment (i.e. the length of copper wire equivalent to inserting zero length of the new material) and give confidence limits.

2. Knowledge of the process by which the following observations (z) were obtained leads one to suppose that x ($=\sqrt{z}$) is normally distributed. Test this supposition by estimating from the sample for the variate x, a = mean deviation ÷ standard deviation and $\sqrt{b_1}$ = (third moment about the mean) ÷ (standard deviation)^3

1·21	0·09	12·96	1·44	0·04
2·89	0·36	3·61	0·25	2·56
0·00	7·84	10·24	2·89	0·49
0·64	2·25	0·16	1·96	0·09
7·84	0·81	0·16	0·36	2·89

Comment on the results in view of the facts that in samples of this size from a normal distribution a rarely (frequency 0·01) lies outside the range 0·8901 to 0·7040, nor $\sqrt{b_1}$ outside the range $\pm 1·061$. Corresponding 0·05 limits are ·8686 to 0·7360 for a and $\pm 0·711$ for $\sqrt{b_1}$.

3. Samples of five cartons filled with powder are taken from the outputs of two automatic filling machines and weighed giving the following excess weights in drams over the nominal weight of the package.

Sample No.	1	2	3	4	5
	9	10	6	7	6
	8	7	6	6	5
1st Machine	9	8	8	6	5
	9	8	8	7	5
	10	10	9	9	7
	11	11	10	10	7
	12	11	10	9	7
2nd Machine	10	8	9	6	5
	12	10	11	9	8
	12	9	10	9	8

Carry out an analysis of variance within and between samples and between machines and discuss the results, supporting your conclusions with numerical values.

4. An assembly of four screws and a plate being made in quantity will be useless for its purpose if its total weight exceeds 100 grams. The screws are purchased and found to have weights normally distributed with a variance of 2 g.^{2} about a mean of 15 g. The size and the material of which the plate is made calls for an average weight of 27·64 g. No sorting or matching being possible, specify a variance for the plate weight which will ensure that in the long run no more than 0·1% of the product is over the specified total weight.

5. A resistance coil to be used as a laboratory standard had, according to its certificate, a resistance of 10 ohms when made. No very precise means of checking its resistance is possible but the following observations were made by a method which experience had shown to be without bias. Is there evidence in these observations of a change in the resistance from its specified value of 10 ohms ?

10·11	10·03	9·98	10·14	9·97
10·25	10·14	10·07	10·03	10·05

6. Write briefly about the statistical aspects of *one* of the following :—(*a*) Precision and accuracy of test methods, (*b*) Student's *t*, (*c*) The need for random selection when taking samples.

7. Prove that the sum of two Poisson variates x_1 and x_2, whose means are μ_1 and μ_2 respectively, is also a Poisson variate. Give its mean value. Samples of 20 articles are taken throughout the day from a process whose history justifies the presumption of a continuing steady mean fraction of defective articles of 0·04. If ten such samples are taken per day state an upper limit to the total number defective in the ten samples which should be exceeded on only $2\frac{1}{2}$% of days.

8. Typewritten circulars may be sent at " printed paper " rates if handed in at a post office in bundles of 20 identical letters. Give a reasoned reply to one who, suspecting two kinds of letters and desirous of using a sampling scheme to confirm or reject his suspicion, asks how many he should examine in a bundle of 20.

If there are, in fact, three letters of one kind and seventeen of another in a particular bundle, what is the chance that the existence of the two kinds will be revealed before the examination of the fifth randomly chosen letter ?

MATHEMATICAL PHYSICS

Examiner : A. W. GILLIES, B.SC., PH.D., F.INST.P.

TUESDAY, 4th June—2 p.m. to 5 p.m.

(*Answer* FOUR *questions*)

1. A function x of the independent variable t satisfies the equation

$$\frac{dx}{dt}+x=f(t)$$

for $t>0$, with $f(t)$ a periodic function of period 2 having the values 1 for $0<t<1$ and 0 for $1<t<2$. If x_n denotes the value of x when t equals the integer n, show that

$$x_{2n}-a=e^{-2}(x_{2n-2}-a)$$

where a satisfies the equation

$$ea = 1-(1-a)e^{-1}$$

Hence show that whatever the initial value x_0, x approaches a periodic solution in which x oscillates between $1/(1+e)$ and $e/(1+e)$. Show that the mean value of this solution is $\frac{1}{2}$ and determine the amplitude of its fundamental component.

2. A string of length $3a$, tightly stretched between two fixed points with tension T carries particles of mass m at distances a and $2a$ from one end. The particles are deflected by amounts x and y respectively perpendicularly to the equilibrium line of the string. Form the equations of motion of the particles when x and y are small compared to a, and the string remains in one plane. Determine the frequencies and describe with the aid of diagrams the nature of the motion in each of the normal modes of the system.

3. A string of mass m per unit length is stretched tightly with tension T between two points. Show that the differential equation of small transverse vibrations is

$$\frac{\partial^2 y}{\partial t^2}=c^2\frac{\partial^2 y}{\partial x^2}$$

in which y is the transverse deflection of a point of the string at x from an origin along the line of the string, and $c^2 = T/m$.

Two such strings lying along the x-axis are joined at $x = 0$, so that for $x<0$, $m = m_1$, and for $x>0$, $m = m_2$. What conditions must be satisfied at $x = 0$? If for $x>0$

$$y = B\sin\omega\left(t-\frac{x}{c_2}\right)$$

determine the solution for $x<0$. Define and determine the reflection and transmission coefficients at the junction.

4. Derive the equation $\frac{\partial\theta}{\partial t}=K\frac{\partial^2\theta}{\partial x^2}$ for the conduction of heat in one dimension.

A plate, bounded by planes $x = 0$ and $x = l$, is at zero temperature at $t = 0$. At this instant the surface $x = l$ is brought to temperature Θ and is maintained at this temperature, while the opposite face is maintained at zero temperature. Show that for $t > 0$ the temperature within the plate is given by

$$\theta = \frac{\Theta x}{l} + \frac{2\Theta}{\pi}\sum_{n=1}^{\infty}\frac{(-1)^n}{n}e^{-\frac{n^2\pi^2Kt}{l^2}}\sin n\frac{\pi x}{l}$$

5. Show that the potential field due to an electric dipole of moment $m\mathbf{k}$ at the origin is $V = mz/(4\pi r^3)$ at the point P with cartesian co-ordinates (x, y, z) or polar co-ordinates (r, θ, φ).

Into a uniform electric field of intensity $E\mathbf{k}$ is placed an uncharged conducting sphere of radius a. Determine the new potential field, and show that the greatest field intensity is of magnitude $3E$ and that the total charge of either sign induced on the sphere is $3\pi a^2E$.

6. State Gauss' divergence theorem, and use it to establish Green's formulae

(i) $$\iiint\left[\varphi\nabla^2\psi + grad\,\varphi\, grad\,\psi\right]dv = \iint\varphi\frac{\partial\psi}{\partial n}ds$$

(ii) $$\iiint\left[\varphi\nabla^2\psi - \psi\nabla^2\varphi\right]dv = \iint\left[\varphi\frac{\partial\psi}{\partial n} - \psi\frac{\partial\varphi}{\partial n}\right]ds$$

A scalar point function V has to satisfy the equation

$$\nabla^2V = -\rho$$

where ρ is a given scalar point function which vanishes everywhere outside a sphere of radius R, with centre at the origin. Show that the value of V at the origin is

$$\iiint\frac{\rho dv}{4\pi r}$$

where r is the distance from the origin to the volume element dv.

7. Determine conditions which must be satisfied by a vector point function $\mathbf{A}$, so that $\mathbf{E} = \dot{\mathbf{A}}$, and $\mathbf{H} = -(1/\mu_0)$ curl $\mathbf{A}$ may satisfy Maxwell's equations in free space, and show that $\mathbf{A} = \mathbf{j}\,A\sin(\omega t - \beta x)\sin(\pi z/p)$ will satisfy these conditions if the constants β, ω and p are suitably related. Show that this value of $\mathbf{A}$ defines a field inside a rectangular channel bounded by planes $y = 0$, $y = q$, $z = 0$, $z = p$, the walls being perfect conductors. Discuss the flow of energy in this field and show that the mean total energy flux is in the direction of the positive x-axis, and is of magnitude $A^2\omega\beta pq/(4\mu_0)$.

8. Discuss the result of the Michelson-Morley experiment, and derive the equations of the Lorentz transformation from an inertia frame Σ to another Σ' which moves relative to the first with constant velocity V in the direction of the x-axis.

A light wave travelling in the x direction has frequency ν referred to Σ. Determine its frequency ν' referred to Σ'.

9. The potential energy of a particle of mass m in a field of force is U for $-a < x < a$, and zero outside this interval. A beam of identical particles each with total energy $\frac{1}{2}U$ is incident from $x = -\infty$ in the direction of the x-axis. Show that the proportion of the incident particles which penetrate the potential barrier between $x = -a$ and $x = a$ is $1/\cosh^2 2\alpha a$ where $\alpha^2 = 4\pi^2mU/h^2$.

ELECTRONICS

Examiner : A. E. DE BARR, B.SC., F.INST.P.

TUESDAY, 4th June—2 p.m. to 5 p.m.

(*Answer* FIVE *questions, including at least* TWO *from each section*)

(*The required numerical information is given at the end of the paper*)

SECTION A

1. Write an account of the conduction of electricity in solids, referring particularly to the factors determining the electrical resistivity of metals, semiconductors, and insulators.

Explain what is meant by the work function of a surface, and describe briefly its importance in (*a*) thermionic emission, (*b*) metal rectifiers.

2. Write an account of the conduction of electricity through gases.

Describe the construction and operation of a sodium vapour lamp as used for street lighting, and give particulars of the electrical circuit associated with the lamp.

3. Draw the equivalent circuit, including inter-electrode capacitances, for a simple triode amplifier feeding a resistive load, and derive an expression for the equivalent input impedance. Hence explain why such a circuit is unsuitable for the amplification of high frequency signals. Why is a pentode more suitable than a triode for this purpose ?

What is the effect, on the properties of the amplifier, of increasing the effective grid-anode capacitance by connecting a condenser between grid and anode ? Indicate two applications of this type of circuit.

4. Explain the operation of a diode rectifier used for the demodulation of a modulated radio signal.

Show that for an unmodulated signal the load presented to the preceding valve by the diode circuit is a resistance of half the value of the series load resistor in the diode circuit. Assume the diode to act as a perfect rectifier and to have a large condenser in parallel with the load resistor.

5. Describe, with diagrams and circuit diagrams to show the essential features, suitable electronic equipment for TWO of the following requirements : (*a*) It is desired to show, on the screen of a cathode-ray oscilloscope, the relation between B and H at 50 c/s for a sample of iron. The field H is proportional to the current (maximum value 1 amp.) in a coil surrounding the specimen whilst the voltage across the coil (maximum value 100 volts) is proportional to $\frac{dB}{dt}$. (*b*) It is desired to compare the intensities of two beams of light, which are allowed to fall alternately, at about 70 c/s, on to a photoelectric cell. (*c*) It is desired to photograph on the screen of a cathode-ray oscilloscope the rise of pressure at a nearby point immediately after the detonation of a small explosive charge.

SECTION B

6. Explain how an electron beam can be focused by (*a*) a magnetic field, (*b*) an electric field. Describe briefly one application of each method, indicating the way in which the field is provided and its approximate magnitude.

The anode and cathode of a vacuum diode are parallel plates 1 cm apart. The cathode is at zero potential and the potential of the anode is given by $V = \sin 2\pi ft$ volt, where f = 50 Mc/s. At time $t = 0$, an electron is at rest near the cathode. Describe its subsequent motion and find (i) its velocity at time $t = 2 . 10^{-8}$ second, (ii) its maximum velocity.

7. Explain briefly how oscillations are maintained in (*a*) a Hartley oscillator, (*b*) a magnetron, (*c*) a multivibrator, (*d*) a dynatron oscillator, and (*e*) a resistance-capacity oscillator.

A triode with a mutual conductance of 1·5 mA/volt is to be used as an oscillator. The parallel-tuned grid circuit has an equivalent series resistance of 25 ohm and a total capacitance of 200$\mu\mu$F. Calculate the minimum value of the mutual inductance between the untuned anode coil and the grid coil in order that oscillations may just be maintained.

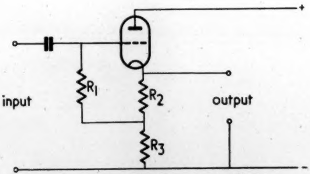
8. Explain the principle and the advantages of push-pull operation in a valve amplifier.

Each of the triodes used in a push-pull Class A power amplifier has a mutual conductance of 6 mA/volt and an anode slope resistance of 1,500 ohm. The combined anode current of 120 mA is fed from a 350 V d.c. supply to the centre tap of a primary winding of an iron-cored transformer, the secondary winding of which is connected to a non-reactive resistor of 2·5 ohm resistance. The ratio of the number of primary turns to secondary turns is 40. Estimate the anode power efficiency of the stage when a sinusoidal signal of 20 volts peak is applied to each valve. (Assume ideal linear characteristics for the valves.)

9. In a single-valve amplifier a fraction β of the output voltage is fed back to the input as negative feedback, and negative current feedback is also applied through a resistance R_f. The anode slope resistance of the valve is R_a and its amplification factor is μ. Calculate from first principles the output impedance of the amplifier.

Explain briefly why the non-linear distortion of the amplifier is reduced by the use of negative feedback.

Calculate the input impedance, output impedance, and voltage gain of the cathode follower stage shown.



$R_1 = 2\text{M}\Omega$, $R_2 = 400\Omega$, $R_3 = 15\text{k}\Omega$

Numerical Data

Electronic charge, *e*	$1{\cdot}602 . 10^{-19}$ coulomb
Electronic mass, *m*	$9{\cdot}107 . 10^{-28}$ g.
Velocity of electromagnetic waves in free space, *c*	$3 . 10^{-10}$ cm sec^{-1}

APPLIED ACOUSTICS

Examiners :

A. E. DE BARR, B.SC., F.INST.P. ; A. T. PICKLES, O.B.E., M.A., F.INST.P.

TUESDAY, 4th June—2 p.m. to 5 p.m.

(*Answer* FIVE *questions, including at least* TWO *from each section*)

(*The required numerical information is given at the end of the paper*)

SECTION A

1. Discuss the factors affecting the propagation of sound in the open air. Illustrate your answer by referring to the sound from a gun, fired on the ground at some distance from the observer.

Calculate the change in the velocity of sound in air if the temperature changes from 19°C to 20°C.

2. Discuss the physical basis of reverberation in rooms and explain what is meant by the reverberation time of a room.

Given that, for air at normal room temperature, the reverberation time T of a room is given by

$$T = 0{\cdot}05 \frac{V}{a} \text{ seconds}$$

where V = volume of room in cubic feet,
a = number of absorption units in sabins (sq. feet),
calculate the reverberation time of a room 15 feet wide × 20 feet long × 10 feet high having
(*a*) 2 open windows, each 4 × 3 feet, on each of the side walls
(*b*) walls of plastered brick (absorption coefficient 0·02)
(*c*) ceiling of plaster on concrete (absorption coefficient 0·03)
(*d*) carpeted floor (absorption coefficient 0·2).

What would be the effect on the reverberation time if there were 20 people in the room ?

(*Coefficient of sound absorption per person 5·0*)

3. Explain how the sound insulation afforded by a wall between two rooms of a building depends upon :
(*a*) the frequency of the sound
(*b*) the thickness of the wall
(*c*) the density of the material of the wall
(*d*) the area of the wall.

A 9 in. solid brick wall, 15 ft. long and 10 ft. high, separates two rooms and gives an average figure for sound insulation of 50 decibels. If a doorway 7 ft. high and 3 ft. wide is now made in the wall, and closed by a door of average insulation 20 decibels, what will be the resultant insulation between the rooms ?

SECTION B

4. Describe how you would calibrate a microphone for use in air. Discuss particularly the factors affecting the accuracy of your calibration.

Describe briefly the design of a microphone suitable for use as a laboratory primary reference standard, and indicate the basic features of the associated electronic apparatus required for use with such a microphone.

5. Describe, and illustrate by means of a diagram, the general features of the human ear. How is the frequency sensitivity distributed along the basilar membrane ?

Explain what is meant by :

(*a*) presbycousis (*b*) masking
(*c*) Haas effect (*d*) combination tones
(*e*) pitch (*f*) threshold of hearing.

Draw a diagram to illustrate the nature and the magnitude of the variation with frequency of the threshold of hearing in the normal ear.

6. Describe and explain the directional pattern produced by a number of point sources of sound arranged at equal small distances along a line and operating in phase. Derive an expression for the directivity pattern of such an array having n sources, spaced at a distance d.

Describe practical uses to which such arrays have been put.

7. Explain how, using a microphone, an analyser, and a meter you would measure the sound-pressure level of a noise emitted from a machine, and show how you would proceed to calculate the loudness of the noise.

Describe briefly some of the steps that can be taken to prevent the noise emitted by a machine from disturbing other workers in the vicinity of the machine.

8. Describe the design, construction and testing of an anechoic chamber.

What factors determine the frequency range over which such a chamber can be used ?

Discuss briefly some of the practical uses of such a chamber.

9. What is a " supersonic bang " ? Describe the general features of the production of such " bangs," and of their transmission through the air.

Explain briefly the significance of the velocity of sound in air for high speed flight and comment on the existence of a " sound barrier."

Numerical data

Ratio of the principal specific heats for air	1·402
Density of mercury	13·6 g.cm^{-3}
Density of air at N.T.P.	1·293 . 10^{-3} g.cm^{-3}

APPLIED OPTICS

Examiners :

A. E. De Barr, B.Sc., F.Inst.P. ; C. A. Taylor, B.Sc., Ph.D., F.Inst.P.

TUESDAY, 4th June—2 p.m. to 5 p.m.

(*Answer* FIVE *questions, including at least* TWO *from each section*)

Section A

1. Give an outline of the Abbe theory of microscopic vision.

Using the Abbe theory as a basis, discuss (*a*) the limit of resolution for a microscope, (*b*) dark-ground illumination in microscopy **and** (*c*) phase-contrast microscopy.

2. Outline the difficulties involved in obtaining quantitative spectral distribution curves by using some form of densitometer and a photograph of the spectrum. How does this method compare with the use of some form of direct photo-electric spectrophotometer in which photography is not involved ?

3. How would you find experimentally the axis of a thin converging lens ?

Describe in detail the procedure you would adopt to set up an optical system with all its components in accurate alignment. Illustrate your answer by referring to a system of four lenses forming a final image, with unit magnification, of a pin-hole illuminated by a compact-source mercury-arc lamp and a condenser. You may assume particular values for the constants of the various components if you wish.

4. Discuss the range of applicability of the paraxial lens formulae and describe ways in which the limitations may be overcome in practical astronomical systems, mentioning particularly the use of aspheric surfaces and of the Schmidt plate.

Outline the techniques used in manufacturing such systems.

5. You are given a sealed box, out of which emerges a strong, parallel beam of sodium light. Explain carefully what experiments you would perform in order to determine the precise state of polarization of the beam. Include experiments on the axial ratio and tilt of any elliptical component present.

If you use any special plates or prisms, describe their construction and function.

6. Discuss the relationships between the energy and the luminosity associated with a beam of light. Include an account of the standard luminosity curves for photopic (light-adapted) and scotopic (dark-adapted) vision and discuss their importance in visual photometry.

SECTION B

7. The temperature of an echelon grating changes during an exposure. If the grating has thirty steps each 1 mm wide and the glass plates are 1 cm thick, calculate what change of temperature will cause :

(*a*) displacement of the spectra by one order ;

(*b*) appreciable broadening of the image.

Derive any formulae you use, and comment on the significance of the results.

(The refractive index of the glass is 1·519, and the temperature coefficient of refractive index is $1{\cdot}4 \,.\, 10^{-6}$ per °C. The linear coefficient of thermal expansion of the glass is $7{\cdot}8 \,.\, 10^{-6}$ per °C and the wavelength of the light used is 5461 Å.)

8. Find graphically, or otherwise, the positions of the cardinal points of an eyepiece consisting of two thin converging lenses separated by a distance d, the focal length of the field lens being $2d$ and of the eye-lens $2d/3$.

A pencil of rays is directed towards a point whose perpendicular distance from the axis of the system is $d/6$ and emerges from the eye lens as a parallel beam. Sketch the path of the rays on a scale diagram of the system, assuming that the pencil just fills the eye lens.

9. Newton's rings are formed between a plane glass plate in contact with a lens of radius of curvature 2,000 cm. With sodium light passing through the air film at 30° to the normal find the diameter of the fifth black ring. Derive any formulae you use.

The experiment is repeated using a mixture of sodium light and light of another wavelength, and it is found that the eighth bright ring of the system formed by the light of the second wavelength coincides exactly with the seventh bright ring with sodium light. Calculate the wavelength of the added light and discuss the effect on the coincidence of placing a film of liquid of refractive index 1·3 between the lens and the plate.

Assume the wavelength of sodium light to be 5893 Å.

SPECTROSCOPY

Examiners :

A. E. DE BARR, B.SC., F.INST.P. ; R. SCHNURMANN, DR.RER.NAT., F.INST.P.

TUESDAY, 4th June—2 p.m. to 5 p.m.

(*Answer* FIVE *questions, including at least* ONE *from Section A*)

(*The required numerical information is given at the end of the paper*)

SECTION A

1. Discuss the factors affecting the width of spectral lines.

The temperature of an echelon grating changes during an exposure. If the grating has thirty steps each 1 mm wide, and the glass plates are 1 cm thick, calculate what change of temperature will cause displacement of the spectra by one order.

(The refractive index of the glass is 1·519, and the temperature coefficient of refractive index is $1{\cdot}4 \,.\, 10^{-6}$ per °C. The linear coefficient of thermal expansion of the glass is $7{\cdot}8 \,.\, 10^{-6}$ per °C and the wavelength of the light used is 5461 Å.)

2. Explain what is meant by the Zeeman effect and discuss briefly its theoretical interpretation. Outline the experimental arrangement you would use to investigate the effect quantitatively.

In an applied field of 30,000 oersted the D_2 line of sodium splits into six components, the displacements of which are $\pm 0{\cdot}47$ cm^{-1}, $\pm 1{\cdot}41$ cm^{-1}, $\pm 2{\cdot}35$ cm^{-1} respectively. Compare this pattern with that of the normal Zeeman triplet and account, in general terms, for the differences.

3. Describe the influence of the Doppler effect on the resolution of hyperfine structure.

In the spectrum of a star the more refrangible component of the double sodium line is found to coincide in position with the less refrangible component of the pair in the solar spectrum. Calculate the velocity of the star and state whether it is moving towards the earth or away from it.

(Assume the wavelengths of the two components to be 5890 and 5896 Å.)

SECTION B

4. Describe the Bohr model of the atom and explain how it accounts for the main features of atomic spectra.

Derive an expression for the wavelengths of the Balmer series of spectral lines and discuss the significance of the Rydberg constant.

5. Discuss the Franck-Condon principle and give the orders of magnitude of electronic, vibrational, and rotational excitation energies.

6. Describe briefly the relative advantages and disadvantages of a photographic and a photoelectric spectrometer for work in the ultra-violet region. Which type of instrument has the greater effective resolving power and why ?

The intensity of a spectral line is assessed by comparison with a reference beam, the intensity of which can be varied. How is the intensity of the reference beam varied in the two types of instrument ?

7. Describe the components of a spectrophotometer for measuring absorption spectra in (*a*) the ultra-violet, (*b*) the visible, (*c*) the infra-red region.

Which is the most critical component of a spectrophotometer ?

8. Describe the procedure you would use in order to calibrate the wavelength scales of (*a*) an ultra-violet spectrophotometer, and (*b*) an infra-red spectrophotometer.

9. Describe the effect of temperature on the structure of absorption spectra, and indicate the changes in the absorption spectrum of benzene when going from room temperature to liquid air temperature.

How would you proceed to analyse a mixture from its absorption spectrum, bearing in mind the indeterminacy of the measured absorption intensities.

Numerical data

Electronic charge, e	$1{\cdot}602 \,.\, 10^{-19}$ coulomb
Electronic mass, m	$9{\cdot}107 \,.\, 10^{-28}$ g.
Velocity of electromagnetic waves in free space, c	$3 \,.\, 10^{10}$ cm sec^{-1}

X-RAYS

Examiners :

A. E. De Barr, B.Sc., F.Inst.P. ; R. F. Farr, M.A., F.Inst.P.

TUESDAY, 4th June—2 p.m. to 5 p.m.

(*Answer* FIVE *questions*)

1. Account briefly for the following in terms of the quantum theory of electromagnetic radiation.

(*a*) The minimum wavelength of X-rays emitted from a given target.

(*b*) The emission of radiation characteristic of the target material.

(*c*) The existence of scattered radiation of wavelength longer than that of the primary radiation.

Calculate the wavelength of the $K\alpha$ radiation of molybdenum, given that the wavelength of the $K\alpha$ radiation of silver is 0·56 Å.

The mass absorption coefficient of molybdenum is 15·0 gm.cm^{-2} for X-rays of wavelength 0·631 Å and 50·2 gm.cm^{-2} for X-rays of wavelength 0·497 Å. Explain these figures and estimate the value of the mass absorption coefficient for X-rays of wavelength 0·814 Å.

(Molybdenum Z = 42
Silver Z = 47)

2. Estimate the relative rates at which heat is generated on the anodes of the rectifying valves and of the X-ray tube in a centre-earthed, half-wave rectifying circuit operating at 100 KVp, 5mA. The characteristics of a high tension rectifying valve under correct operating conditions are given below.

anode voltage	0	650	1,020	1,400 volts
anode current	0	3	4·5	6·0 mA

How is the result of your calculation exemplified in the design of the valve and tube ?

Under what circumstances might there be a marked change in this ratio and what would then be the effect upon

(*a*) the operation of the rectifying valve ?

(*b*) the radiographic result ?

3. An X-ray equipment normally operates from 240 V a.c. mains (50 c/s) and supplies an X-ray tube at 150 KVp and 10 mA. What would be the general effect of an uncompensated fall of mains voltage to 215 V upon the X-ray output ? What effect would you expect to observe upon radiographs taken with the machine ?

Describe the possible causes of such fluctuations of line voltage. What methods may be used to stabilize the X-ray apparatus against their effects ? Would you expect a fall of mains frequency, say to 48 c/s, to have any observable effect ?

4. Discuss the importance of

(*a*) the angle at which the target is viewed, and

(*b*) the smoothness of the focal area

in regard to the useful output of an X-ray tube.

The following test radiographs are taken of a lead straight edge, set parallel to a cassette, the focus-film distance being 50 cm. In the first three, the X-ray film is used alone and the distance between the test-object and the film is

A	5 cm
B	7·5 cm
C	10 cm

In the fourth (*D*) the same type of film is used with intensifying screens and the test object is in contact with the cassette.

In case *B* the blurring of the shadow is measured by a microdensitometer to be 1·1 mm. The unsharpness in case *D* is judged by eye to be half-way between that of *A* and *B*. What would you expect the blurring to be if the test *C* is repeated using intensifying screens ?

5. Explain the significance of the terms

(*a*) roentgen. (*b*) air-equivalent wall.

An ionization chamber has an air-equivalent wall and its effective air-volume is 100 cc. When placed 1 metre from a radiographic cobalt-60 source of small dimensions, the ionization current developed a p.d. of 0·85 volts across a resistance of 10^{10} ohms which forms part of a dose-rate meter.

Estimate (*a*) the effective strength of the cobalt source ; (*b*) the thickness of lead necessary to reduce the dose-rate at 50 cm from the bare source to a value of 10^{-5} r/sec.

Calculate the dose-rate upon the surface of a lead sphere of this radius, with source at its centre. In practice, the dose-rate there is found to have a rather higher value. Account for this.

(K factor for cobalt 60 = 13·5 r/hr at 1 cm.

Effective h.v.l. in lead for cobalt 60 gamma radiation = 1·2 cm)

6. What is the relation between (*a*) the density, (*b*) the contrast, and (*c*) the latitude of a radiograph ? Upon what factors do they separately depend.

An aluminium casting consists of a disc 5·72 cm in thickness, surrounded by a flange 1·27 cm thick. The densities of blackening of the corresponding areas of a correctly exposed radiograph are 0·67 and 2·03 respectively.

There is an air-cavity 4·8 mm long in the direction of the axis of the disc, half-way through the thicker portion of the casting. Ignoring the effects of scattered radiation, estimate the contrast of this shadow with its surroundings.

What would you expect the contrast to be if 75% of the radiation reaching the film was radiation scattered by the casting ?

7. Describe the processes which occur when X-rays fall upon a zinc sulphide screen. Upon what factors do the brightness and colour of the light emitted depend and what determines the optimum thickness of such a screen used for fluoroscopy ?

Describe some uses of fluoroscopy in non-destructive testing and discuss its limitations when compared with radiography.

8. Explain, with particular reference to the alkaline halides, how X-rays can be used to determine the structure of crystals.

A rotation photograph of a cubic crystal of cell side 7·7 Å is taken about the *c* axis using radiation of wavelength 1·54 Å. Which of the planes 103, 104, 204 will have an opportunity of reflecting the X-rays ?

9. Write an essay upon the possible hazards from the use of X-rays and radio-isotopes in radiography, and the measures taken to reduce them.

MATHEMATICS I

Examiner : A. W. GILLIES, B.SC., PH.D., F.INST.P.

WEDNESDAY, 5th June—9.30 a.m. to 12.30 p.m.

(*Answer* SIX *questions*)

1. Find the real root of the equation $x^3 + 3x + 2 = 0$ correct to three decimal places, and obtain the real and imaginary parts of the complex roots to two decimal places.

2. (i) Show that $\int_0^\infty e^{-x}x^n dx = n!$

(ii) Evaluate $\int_0^1 \frac{x^2dx}{(1+x)^2(1+x^2)}$ correct to four decimal places.

3. Show than $\tanh(\alpha + i\beta) = \dfrac{\sinh 2\alpha + i\sin 2\beta}{\cosh 2\alpha + \cos 2\beta}$

If $z = \tanh \frac{1}{2}(\log 2 + i\theta)$ show that as θ varies between 0 and 2π, the point z describes a circle on the complex plane with centre at (5/3, 0) and radius 4/3.

4. If $F(a)$ denotes the integral $\int_0^\pi \{f(x) - a\sin x\}^2 dx$, express $F'(a)$ and $F''(a)$ as integrals with respect to x between 0 and π. Hence obtain an expression for a in order that $F(a)$ may be a minimum, and find this value of a when $f(x) = x(\pi - x)$.

5. The displacement y of a system B of unit mass is to follow as closely as possible the displacement x of system A. To obtain this, forces $(h^2+k^2)(x-y)$ and $2h(x-y)$ act on B, h and k being positive constants. Prior to $t = 0$, A and B are at rest with $x = y = 0$. At $t = 0$, A suddenly starts to move with constant velocity v. If z is the displacement of A relative to B show that

$$\ddot{z} + 2h\dot{z} + (h^2+k^2)z = 0$$

Show that the displacements of A and B are equal whenever t is an integral multiple of π/k. If $h = 1$, $k = 2$ and $v = 1$ find the greatest relative displacement.

6. In a table of values of sinh x and cosh x to nine figures against x at intervals of 0·001 between $x = 2$ and $x = 10$, it is stated that " to interpolate in the table, to obtain the full accuracy the following formulae may be employed :

$$\sinh(x+p) = (1+\tfrac{1}{2}p^2)\sinh x + p\cosh x.$$
$$\cosh(x+p) = (1+\tfrac{1}{2}p^2)\cosh x + p\sinh x.$$

linear interpolation will yield at least six figures throughout." Explain this statement, show how the formulae are derived, and justify their use in this way.

7. In a certain frequency distribution the relative frequency of occurrence of a value between $x - \frac{1}{2}dx$ and $x + \frac{1}{2}dx$ is $Axe^{-x}dx$, the quantity x being positive. Determine the value of the constant A, and show that the mean of the distribution is 2, the mode is 1, and the median is approximately 1·7.

8. A force $\mathbf{F}$ acts at a point having the position vector $\mathbf{r}$. The vector moment of the force about 0 is $\mathbf{r}_\wedge\mathbf{F}$. Show that the scalar mechanical moment of the force about a line through 0 in the direction of a unit vector $\hat{\mathbf{a}}$ is $\mathbf{r}_\wedge\mathbf{F}.\hat{\mathbf{a}}$.

A certain system of forces is equivalent to a resultant $\mathbf{F}$ acting at 0 together with a couple of moment $\mathbf{G}$. Show that the vector moment of the system about the point with position vector $\mathbf{r} = (\mathbf{F}_\wedge\mathbf{G})/\mathbf{F}^2 + \lambda\mathbf{F}$ is parallel to $\mathbf{F}$, λ being an arbitrary scalar factor.

[The relation $(\mathbf{a}_\wedge\mathbf{b})_\wedge\mathbf{c} = (\mathbf{a}.\mathbf{c})\mathbf{b} - (\mathbf{b}.\mathbf{c})\mathbf{a}$ may be quoted]

9. The ends of a uniform rod of mass m and length 21 slide smoothly in guides along the x and y axes respectively, the y-axis being vertical. The rod is released from rest with one end at the origin, the other at $x = 2l$. Show that its angular velocity, when inclined at an angle θ to the horizontal, is $[3g\sin\theta/(2l)]^{\frac{1}{2}}$, and determine the magnitudes and directions of the reactions at the two ends (*a*) immediately after it is released, (*b*) when it has turned through a right angle.

MATHEMATICS II

Examiner : A. W. GILLIES, B.SC., PH.D., F.INST.P.

WEDNESDAY, 5th June—2 p.m. to 5 p.m.

(*Answer* SIX *questions*)

1. What is meant by a simple periodic function ? In what respects may two simple periodic functions differ ? Show how a simple periodic function may be represented by (*a*) a rotating vector, (*b*) a complex number.

A number of simple periodic functions all of the same period are added together. Show that if the initial phases of all lie between $-\frac{\pi}{2}$ and $+\frac{\pi}{2}$, then the initial phase of the sum is also in this range.

2. The current in a certain rectifier is proportional to $f(\omega t)$ where $f(\theta)$ has period 2π and

$$\begin{aligned} f(\theta) &= \cos\theta - \cos\alpha && \text{for } -\alpha < \theta < \alpha \\ f(\theta) &= 0 && \text{for } -\pi < \theta < -\alpha \quad \text{and} \\ & && \text{for } \alpha < \theta < \pi \end{aligned}$$

α being a constant. Determine the ratio of the amplitude of the fundamental to the constant term of the Fourier expansion of the current, and show that this ratio approaches the limit 2 as α tends to zero.

3. Show that each of the integrals $\int_C \frac{-y\,dx + x\,dy}{\sqrt{(x^2+y^2)}}$ and $\iint_R \frac{dx\,dy}{\sqrt{(x^2+y^2)}}$ has the value $8a \log(1+\sqrt{2})$; R denoting the region inside a square of side $2a$ with centre at the origin and sides parallel to the axes, and C denoting the boundary of this region.

4. The displacements x, y of two connected masses satisfy the simultaneous equations :

$$5\frac{d^2x}{dt^2} + 109x + 32y = 0$$

$$32x + 5\frac{d^2y}{dt^2} + 61y = 0$$

By forming the differential equations for $\xi = 2x + y$ and $\eta = x - 2y$, or otherwise, show that the motion of each mass is a sum of two simple periodic motions. How must the displacements and velocities at $t = 0$ be related if the subsequent motion is to be simple periodic with the higher frequency ?

5. (i) Show that the equation

$$\frac{\partial}{\partial r}\left(r^2\frac{\partial V}{\partial r}\right) + \frac{1}{\sin\theta}\frac{\partial}{\partial\theta}\left(\sin\theta\frac{\partial V}{\partial\theta}\right) = 0$$

has a solution of the form $V = r^3(\cos\theta + a\cos^3\theta)$, and determine the value of a.

(ii) If $\dot{x} = u^2 - v^2$ and $\dot{y} = 2uv$, express du and dv in terms of dx and dy; hence show that

$$\frac{\partial u}{\partial x} = \frac{u}{2(u^2 + v^2)}$$

and determine $\partial u/\partial y$.

6. Use the method of dimensions with fundamental units time T, electric potential E, and charge Q to show :—

(i) that the energy of a condenser of capacitance C, charged to a potential V is proportional to CV^2.

(ii) That the resonant frequency f of a circuit of inductance L and capacitance C is proportional to $(LC)^{-\frac{1}{2}}$.

(iii) That if the circuit in (ii) also contains resistance then f^2LC is a function of CR^2/L. One such circuit has twice the inductance and half the capacitance of another. How must their resistances be related so that the resonant frequencies may be equal ?

7. Sketch the curve whose equation in polar co-ordinates is $r^2 = 2 \cos 2\theta$ and show that its total length is given by

$$8\int_0^{\sqrt{2}} \frac{dr}{\sqrt{(4 - r^4)}}$$

Indicate the difficulties which arise in attempting to evaluate this integral numerically. Show that the substitution $r = \sqrt{2} \sin \varphi$ reduces it to a form to which Simpson's rule or the "$\frac{3}{8}$ths rule" may be applied, and hence obtain an approximate value for the length of the curve.

8. A solid tetrahedron is bounded by the co-ordinate planes and by the plane

$$\frac{x}{a} + \frac{y}{b} + \frac{z}{c} = 1$$

Its density ρ varies according to the equation

$$\rho = \rho_0\left(1 - \frac{z}{c}\right)$$

ρ_o, a, b, c, being constants. Find the mass of this solid, show that its mean density is $\frac{3}{4}\rho_o$, and determine the co-ordinates of its centre of mass.

9. An equilateral triangle, formed by three uniform rods each of mass m and length a, rests in a vertical plane on two smooth pegs at the same level and distant b apart, with one rod below the pegs. Show that the potential energy V of the triangle is given by

$$V = C - \sqrt{3}mg(b \cos 2\varphi + a \sin \varphi)$$

where C is a constant, and φ is the angle between the median through the uppermost vertex and the horizontal. Show that if $a < 4b$ there are three equilibrium positions, the symmetrical position being unstable.

PURE PHYSICS III — ELECTRICITY AND MAGNETISM

Examiner : PROFESSOR J. G. WILSON, M.A., PH.D., F.INST.P.

THURSDAY, 6th June—9.30 a.m. to 12.30 p.m.

(*Answer* FIVE *questions*)

1. Give an account of the way in which the Van de Graaff generator has developed, explaining the reasons which have led to this development.

What are the special advantages of this type of generator ?

2. " The precision potentiometer is probably the most important instrument in the field of electrical measurement." Discuss this statement.

3. Show how Maxwell's equations are derived from experimental observations, and from them obtain the wave equation for plane electromagnetic waves.

Indicate the behaviour of such a plane wave if it is incident normally on the surface of a material of conductivity σ.

4. Discuss the features which determine the performance of a moving coil galvanometer, with special reference to the measurement of potential and charge.

Give an indication of the practical limits of performance.

5. Obtain an expression for the instantaneous current in a circuit consisting of a condenser and an inductor (the resistance of which is not negligible) in series, when a variable potential $E_0 \sin \omega t$ is applied.

At what frequency will the r.m.s. current be a maximum ? Explain how the current over a range of frequencies near this value depends upon the values of the circuit elements.

6. Explain what is meant by the terms *magnetic induction* (B), *intensity of magnetization* (I) and *field strength* (H), and obtain a relation between these quantities.

Show how you would investigate the change of induction of a ferromagnetic specimen when the applied field is varied, and indicate the form and significance of the result.

7. Discuss the difficulties which are encountered in the construction and operation of a direct current amplifier, and explain how these may be minimized.

Give an example of a situation in which it is possible to modify apparatus which would normally yield a direct current response so that an alternating current output can be obtained.

8. Describe the principles of design of a modern mass spectrograph, and show how the use of this instrument allows a scale of atomic masses to be constructed.

What is the importance of a series of accurate atomic mass values ?

9. Explain clearly the reasoning leading from observations of the scattering of α-particles at a gold foil to the concept of the atomic nucleus.

Why would you expect the scattering distribution to be modified if the target were of beryllium rather than of gold ?

PRACTICAL PHYSICS

Examiners :

A. E. De Barr, B.Sc., F.Inst.P. ; J. Yarwood, M.Sc., F.Inst.P.

FRIDAY, 7th June

(*Two questions selected by the Examiner will be allotted to each candidate*)

1. Find the viscosity of water by a continuous flow method.

2. Determine the modulus of rigidity of a steel wire by an oscillation method.

3. Find the fundamental interval of the platinum resistance thermometer provided.

4. Find the temperature of a flame by two different methods.

5. Use a magnetron valve to find e/m.

6. Investigate the variation of the resistivity of germanium with the reciprocal of the absolute temperature.

7. Investigate the rotatory dispersion of quartz.

8. Find Poisson's ratio for glass by means of an optical interference method.

9. Determine the nature of the given electrical network where access is provided to two terminals only.

10. Construct a valve oscillator and determine, by reference to a standard, the maximum and minimum frequencies of the oscillatory current it generates.

11. Use a coarse diffraction grating to measure the wavelength of sodium light.

12. Determine the Rydberg constant for the hydrogen atom.

COMMENTS OF THE EXAMINERS

Physics I — Professor J. G. Wilson

Forty-nine candidates answered this paper, but of these about half-a-dozen made no serious effort. The general standard of work was disappointing, only a very few candidates showing sustained competence in even the routine parts of questions. The presentation tended to be poor and the spelling in several papers was disgraceful ; in one script "speech," "feeling," "lever," "rapid," "idea," "below," "coming," "research," and "laboratory" were among the more familiar words mis-spelt. The following notes refer to individual questions.

Q. 1. (34 answers) Many candidates had difficulty with simple, precise definitions ; very few related Poisson's ratio to all three moduli.

Q. 2. (14 answers) The answers were of a superficial character and the majority of candidates made no attempt to discuss principles.

Q. 3. (16 answers) This question was almost certainly too difficult for all candidates, most of whom gave up after finding that they could not do the first part. Among the few who attempted the last part there seemed to be little understanding of the nature of the problem

Q. 4. (10 answers) In many ways the answers to this question were the most encouraging in the whole paper. Candidates attempting it were quite certainly thrown back on their own resources to decide what to say about the problem, and almost all of those attempting it made worth-while points.

Q. 5. (27 answers) More than half of those answering this question did not appear to know what Fourier analysis is, and only a very few gave a precise and clear statement. Good practical examples did not prove easy to find and almost all answers to the last section were irrelevant.

Q. 6. (43 answers) This was the most popular question, and the answers started badly insofar as no candidate gave a correct statement of Newton's Law of Gravitation. The nature of the problem was generally well understood, but the majority of candidates were quite unable to put it into manageable analytical form. A number of candidates undertook the simpler problem of comparing the periods of the pendulum at the surface and at the mantle-core interface, then proceeding to guess (always wrongly) how the period would vary in the intervening region.

Q. 7. (20 answers) The first part of this question was on the whole soundly done, the latter parts produced a wide range of answers, from some that were really good to many which had little bearing on the matter under discussion. Some candidates, at least, did not appear to have read the question.

Q. 8. (38 answers) This was a popular question, and about half of those attempting it gave a fairly good description in the first part. Only a minority, however, gave any indication of uncertainty in the status of the theory they discussed. Many candidates had material to answer the second half of the question, but this was a section in which powers of selection and expression showed up very badly.

Q. 9. (26 answers) The answers here were not encouraging, hardly any candidate showing any sign that he had attempted to plan an answer covering the physical features of the situation. Some answers were in no sense a serious essay in physics.

Taking the paper as a whole it is difficult to believe that some candidates have made any progress in knowledge, still less in understanding and command of the subject, since the more elementary examinations upon which so many have claimed partial exemption from the Graduateship examination. It is, on the other hand, probably satisfactory that the good candidates tended to stand out from the general level.

Physics — Professor H. Lipson

It is pleasant to record that more than half the candidates passed this paper, but the pleasure is rather dimmed by the realization that the success was entirely on heat, and then only on the descriptive questions and bookwork. The light questions were very poorly answered, as the following detailed comments show.

Q. 1. Methods of measuring temperature were well known and some essays were very good. Others, however, dismissed the physics of the various processes too lightly, and some showed no attempt to put the topics in any systematic order.

Q. 2. The principles of the Van der Waals equation were clearly described, and the analysis of the equation to produce the critical constants was extremely well done. The main fault was the lack of appreciation of the relationship of the Van der Waals curve to the process of liquefaction.

Q. 3. This question on thermal conductivity was not popular, and few that attempted it knew how to deal with the production of heat within the conductor. This was also the stumbling block to the experimental part of the question, which was designed mainly to see how candidates would produce heat uniformly within a conductor.

Q. 4. Enthalpy seemed to be well-known and understood. Some candidates tried to make the question a mathematical one, but in general candidates kept to physical principles very well.

Q.5. Although black-body radiation was adequately defined, the description of the details of the spectrum—particularly the wavelength minimum—was not well done. A few candidates knew of the problems raised by this spectrum, and of their final solution in terms of quantum theory, but the general response to this extremely important physical topic was poor.

Q. 6. Surprisingly few candidates knew that spherical aberration is a specific aberration, and there was some waste of time on general theory. The problem was poorly answered ; admittedly it was long and tedious, but considerable credit was given for reasonably sensible attempts. Candidates should explain clearly each step of their mathematics in this type of question.

Q. 7. Double refraction was reasonably well described, but the simple problem baffled almost everybody. Few candidates drew any diagrams, although these would almost have solved the problem for them. (This indeed is a general complaint ; a good clear diagram will often serve better than much writing.)

Q. 8. The answers to this question were farcical. Candidates did not understand the question, and did not realize that the image of a diffraction grating is formed by interference of the orders of diffraction—the essential idea in Abbé theory.

Q. 9. There were a few excellent descriptions of the colour triangle and its implications, but on the whole the answers were disappointing. Some were on far too low a level.

MORE ADVANCED PHYSICS —
Professor H. Lipson

On the whole, the answers to this paper were poor. Few candidates were able to tackle more than two questions reasonably successfully, and resorted to meaningless phrases for the others—for example " Electrons are more easily scattered than X-rays." Detailed criticisms of the answers to the various questions are as follows.

Q. 1. Candidates knew that X-rays are scattered by electrons but not that electrons are scattered by potential gradients and neutrons by the nucleus. The reflection concept of X-ray diffraction was not understood, and although Bragg's law was derived by most candidates, none knew how to apply it to the determination of a simple crystal structure.

Q. 2 and Q. 3. These relatively classical questions — on magnetism and light — were very unpopular. Few candidates attempted them and none knew of Sucksmith's work on the former and Tolansky's on the latter.

Q. 4. The quantum numbers applied to a single atom seemed to be well understood. It was not known, however, that Pauli's principle applies also to the conductivity electrons in a crystal and thus that they have high enough velocities to be diffracted by the crystal lattice—an essential point in the Brillouin-zone theory of conductivity.

Q. 5. The question on photoelectricity was answered relatively well. Millikan's photoelectric apparatus was satisfactorily described, although the method of deriving results from it was not usually clearly stated. Nor was emphasis laid upon the striking fact that the slope of the graph relating frequency to the potential necessary to stop emission was found to be constant for all substances. Are facts such as this now being accepted too casually ?

Little was known of the theory of the barrier-layer photocell.

Q. 6. Millikan's method of determining *e* was well described, but not the use of ruled gratings for measuring X-ray wave-lengths. Only one candidate knew that the latter experiments depended upon the existence of total external reflection.

Q. 7. The wave properties of moving particles were reasonably well understood. The experiments of Thomson and of Davisson and Gerner were well described, and most candidates realized that they provided the basis for the electron microscope. Few, however, described the instrument in any detail.

STATISTICS — Mr. E. D. van Rest

Of the four candidates entered, one failed to present himself and one passed.

There was a general weakness in the form of the words chosen to express the results, a fault which in the examiner's opinion leads directly to a failure to discuss and interpret the results adequately and correctly.

In most of the questions the method expected to be used was not explicitly stated and this seemed a source of difficulty ; in several answers a wrong or a poor method was adopted.

APPLIED PHYSICS — Mr. A. E. De Barr

Whenever possible the questions in the Applied Physics papers are set so as to have a direct bearing on the applications of the particular branch of physics concerned, and are, as a result, often rather long. Candidates should realize, however, that satisfactory answers can be given in the time available, and that, therefore if they find themselves involved with pages of formulae, or long descriptions, they are probably missing the point of the question. This year, as in previous years, this has happened all too often.

ELECTRONICS — Mr. A. E. De Barr

Q. 1. This was the most popular question, and most candidates showed at least a superficial acquaintance with the jargon. It was however a little disturbing to find how few of them really knew the essential difference between metals and insulators — most candidates attributed this to the width of the " forbidden " zone !

There were some elegant, but uncalled for, descriptions of the manufacture of metal rectifiers but few explanations of their properties.

Q. 2. Although the sodium lamp is specifically mentioned in the syllabus, no candidates knew anything about the type of electrical circuit used with such a lamp.

Q. 3. The equivalent circuit proved too much for most candidates and, although there were some brave attempts, not one was able to derive the expression for the input impedance.

Q. 4. Three candidates only answered this question, one of them achieving full marks.

Q. 5. In general the answers to this question were good, although there were some examples of misplaced ingenuity — in particular the candidate who, in answer to part (*b*), devised an arrangement for rendering the photocell inactive for one half of each cycle so that the output from the photocell should be proportional to the intensity of one beam of light.

Q. 6. Most candidates knew something of the way in which an electron is deflected by electric and magnetic fields, but few of them had any idea of how focusing effects are obtained.

The second part of this question was so very easy that it is really surprising that not one correct answer was obtained—usually because the constants of integration were omitted !

Q. 7. The first part of this question was well answered, but as usual, the numerical portion was generally ignored.

Q. 9. The valve data were inadvertently omitted from the second part of this question, and this may have created extra difficulty for some candidates. However, even the straightforward first part of the question led to the most complicated formulae.

PHYSICS III — Professor J. G. Wilson

Only seven candidates took this paper and of these, three (including the two gaining the highest marks) attempted only four questions. The range of quality among the candidates was most marked. The following notes refer to questions 4, 5, 6 and 8, all of which attracted more than three answers, it is pleasant, however, to record that the only answer to question 2 was quite outstandingly good.

Q. 4. (4 answers) The answers to this question were indifferent, and one candidate at least can never have seen inside the case of a galvanometer. The whole question of performance as it is controlled in the constructional constants was very poorly understood.

Q. 5. (6 answers) Three candidates answered the first part of the question well, the others made serious errors. The last part was not well done. What was asked for was almost certainly known to most candidates, but the presentation required was not quite familiar and once again disturbing weakness in bringing out exactly what was asked for was shown.

Q. 6. (6 answers) Apart from one half-hearted attempt, all answers to this question gained about half marks ; there was no really good answer. Most candidates found difficulty in explaining the meaning of *magnetic induction*, etc., and in deriving the relation between these quantities (as opposed to writing it down). The descriptive part was fairly well done but the discussions of the experimental result were very thin.

Q. 8. (6 answers) This question yielded miserable answers. Only one candidate referred to any *modern* instrument, no refinement of principle was mentioned, no reference was made to any part of the procedure of establishing a mass scale, and even the crudity of some of the diagrams could not conceal an utter lack of understanding of the instrument.

PRACTICAL PHYSICS — Mr. A. E. De Barr and Mr. J. Yarwood

Three features of the practical examination call for comment :

1. Too many candidates have difficulty in making use of their theoretical knowledge during the Practical examination. Candidates should be able, not merely to make the necessary measurements, but also to make use of their results to calculate the quantities required.
2. Insufficient attention is paid to the consideration of possible errors.
3. It is recommended that students should be asked more frequently to undertake problems during their training in practical physics. Too often, the candidate has only worked from instruction sheets during his course and is therefore somewhat at a loss when confronted with a problem.

Proceedings of the Thirty-seventh Annual General Meeting

The Thirty-seventh Annual General Meeting of the Institute was held on July 12, at 4.45 p.m. in the Clarendon Laboratory, Oxford. Mr. O. W. Humphreys (*President*) was in the Chair. A quorum being present, the Deputy Secretary read the notice convening the meeting. The Minutes of the previous Annual General Meeting held on July 16, 1956, were read and approved and were then signed by the Chairman.

Dr. A. J. Maddock and Mr. E. H. S. van Someren (*Fellows*) were appointed scrutineers of the ballot for election to the Board. The President announced that the Board had appointed Professor E. A. Owen to fill the casual vacancy for a Vice-President caused by the election of Professor F. A. Vick as Honorary Secretary.

On the proposal of Dr. J. Taylor (*Honorary Treasurer*), seconded by Dr. A. C. Menzies (*Fellow*), it was unanimously resolved that the accounts and balance sheets for the year ending December 31, 1956, be adopted. Professor F. A. Vick (*Honorary Secretary*) moved the adoption of the report of the Board for 1956 and this was seconded by Mr. D. T. R. Dighton (*Associate*). The resolution was carried unanimously.

Having received the report of the scrutineers the Chairman declared the following to be elected to fill the vacancies on the Board which will occur on September 30, 1957 :

President :	Mr. O. W. Humphreys
Vice-President :	Professor E. C. Stoner
Honorary Treasurer:	Dr. J. Taylor
Honorary Secretary :	Professor F. A. Vick

Ordinary Members of the Board :
Mr. F. Oldham and Dr. J. Thewlis.

Messrs. Knox, Cropper and Co. were elected auditors for the year 1957.

Votes of thanks were moved to the President, Honorary Officers and members of the Board, the Honorary Officers of Branches and Groups and the bodies which have allowed the use of their rooms during the year for meetings. These were carried with applause.

The Register

ELECTIONS TO MEMBERSHIP

THE FOLLOWING ELECTIONS WERE MADE BY THE BOARD ON JULY 2, 1957

An asterisk (*) indicates transfer from another grade

FELLOWS

*Berz, Feodora, Ph.D., Senior Mathematical Physicist, Mullards Research Laboratories, Salfords, Surrey.

*Deacon, Edgar Leonard B.Sc., Principal Research Officer, C.S.I.R.O., Australia.

*Farrands, John Law, B.Sc., Ph.D., Principal Scientific Officer, Defence Standards Laboratories, Victoria, Australia.

*Fowweather, Frank, B.Sc., Ph.D., Lecturer, College of Science and Technology, Manchester.

*Gosling, Raymond George, B.Sc., Ph.D., Lecturer, Queen's College, University of St. Andrew's.

*Hayward, Francis Walter, B.Sc., Liaison Officer, Albert E. Reed & Co. Ltd., Central Laboratory, Maidstone, Kent.

Lamb, Willis Eugene, M.A., B.Sc., Ph.D., Sc.D., Nobel Laureate, Wykeham Professor of Physics, University of Oxford.

*Stanley, Eric, B.Sc., Ph.D., Lecturer, College of Science & Technology, Manchester.

*Tipton, Henry, M.Sc., Senior Research Officer, British Cotton Industry Research Association, Shirley Institute, Manchester

Young, Stuart Astley, M.A., D.Phil., Chief Nuclear Physicist, Atomic Power Constructions Ltd., London.

ASSOCIATES

*Blackler, Francis Geoffrey, B.Sc., Head of the Cathode Ray Tube Development, Mullard Radio Valve Co. Ltd., Surrey.

Blears, Donald Geoffrey, B.Sc., Senior Chemist, Associated Ethyl Co. Ltd., Cheshire.

Bose, Arabinda, B.Sc., Research Fellow, Chittaranjan Cancer Hospital, Calcutta.

*Causon, Alan Charles, M.Sc., Assistant Chief Physicist, De Haviland Central Laboratories, Middlesex.

Frame, John Cargill, M.A., Lecturer, Moray House Training College, Edinburgh.

Gerrard, Anthony, B.Sc., Assistant Lecturer, College of Technology, Bristol.

Gray, Thomas Philip, B.A., Technical Officer, Imperial Chemical Industries, Ltd., London.

Hamberger, Sydney Maxwell, B.Sc., Scientific Staff, The General Electric Co. Ltd., Wembley.

Hamon, Bruce Valton, B.Sc., B.E., Principal Research Officer, C.S.I.R.O., Australia.

Hunt, Charles James, B.Sc., Assistant Lecturer, College of Technology, Portsmouth.

Johnson, Thomas William, B.Sc., Senior Scientific Officer, British Iron and Steel Research Association.

Leake, Bernard William, B.Sc., Senior Microwave Engineer, Decca Radar Ltd., Surrey.

*Lee, John Gwyn William, B.Sc., Assistant Chief Fusing Engineer, De Haviland Propellers Ltd., Hatfield, Herts.

*McLean, Ian Weymouth, B.Sc., Assistant Lecturer, University of Malaya.

Mahadeva Iyer, H., M.Sc., Senior Scientific Assistant, Naval Physical Laboratory, Cochin, India.

Mander, Harold Frederick William, B.Sc., Lecturer, Enfield Technical College, Middlesex.

Martin, Ernest Hubert Bernard, M.Sc., Staff Education Officer, Directorate of Educational Services, Air Ministry, London.

Matz, Arthur Woolf, B.Sc., A.R.C.S., Mathematical Physicist, Hivac Ltd., Middlesex.

Medlin, Edwin Harry, B.Sc., Ph.D., Lecturer, University of Adelaide.

Morgan, John Smith, M.A., Senior Lecturer Robert Gordon's Technical College, Aberdeen.

Stuart, John Duff, M.A., Ph.D., Head of Mathematics and Physics Department, Robert Gordon's Technical College, Aberdeen.

West, Margaret Elizabeth Joy, M.Sc., Physics Teacher, The Northern Grammar School for Girls, Portsmouth.

*Wright, John Evelyn, M.Sc., Project Leader British Telecommunications Research Ltd., Taplow, Bucks.

*Young, Frederick Ronald, M.A., Head of Physics Department, County Grammar School, Harrow Weald, Middlesex.

GRADUATES

Barrat, Sydney, B.Sc., Assistant Physics Master, James Watt Secondary Technical School, Smethwick.

*Davies, Henri Gwyn, B.Sc., National Service.

Day, Robert John, B.Sc., Technician, A. V. Roe & Co. Ltd., Manchester.

Gilding, David Brian, B.Sc., Technical Engineer, Bristol Aeroplane Co. Ltd., Bristol.

Gradwell, Peter Reginald, B.Sc., Science Master, Queen Elizabeth Hospital, Bristol

*Hayes, David John, B.Sc., Assistant Physicist, Bristol Aero-Engines Ltd., Bristol.

Hill, Roland John, B.A., Graduate Trainee, Rolls-Royce, Ltd., Derby.

Maher, Peter Francis, B.Sc., Technical Assistant, Albert E. Reed & Co. Ltd., Maidstone, Kent.

Peirce, Terrence James, B.Sc., Research Student, University of Sheffield.

Renouf, Thomas Joseph, B.Sc., Demonstrator, Royal Military College of Science, Shrivenham.

*Tan, Beng Keat, B.Sc., Meteorological Officer, Malaya Meteorological Service, Malaya.

*Thomas, Derek Lewis, B.Sc., National Service.

*Treacy, Edmond Brian, B.Sc., Science Teacher, Department of Public Instruction, Australia.

Truman, Norman Nathan, B.Sc., Research Student, Queen Mary College, London.

18 students were also admitted.

The Institute's Journals

PRINCIPAL CONTENTS OF THE AUGUST, 1957, ISSUES

Journal of Scientific Instruments: Volume 34, No. 8

SPECIAL ARTICLE

Ultra-high vacua. By J. Yarwood, F.Inst.P. (*The Polytechnic, Regent Street, London*).

The use of the ionization gauge both as a pump and as a measuring instrument in the pressure range from 10^{-6} to 10^{-11} mm of mercury is discussed. Experimental results indicate that Alpert's claims regarding electrical pumping speed are justified provided that the initial pressure is sufficiently low. Suggestions are made regarding the disparities between Alperts results and those of other workers. The omegatron is described and a short survey given of those factors which set the limit to the lowest pressures attainable in a glass envelope.

ORIGINAL CONTRIBUTIONS

The recording of electron diffraction patterns from single crystals using the Metropolitan-Vickers type E.M.3 electron microscope. By R. E. Burge, H. R. Munden, and C. D. Curling (*Wheatstone Physics Laboratory, University of London, King's College, London*).

The design and construction of two additions to the Metropolitan-Vickers Type E.M.3 electron microscope which are useful in the study of the electron diffraction by single crystals are described. One addition, an adjustable rectangular diffraction aperture, is used to reduce the diffraction area selected at the specimen to a minimum, while the other, two pairs of deflector plates at right angles to which saw-tooth waveform voltages are applied, is useful in the accurate measurement of the intensities in single crystal patterns.

A half-silvered mirror tangentimeter. By H. J. G. Hayman, and F. Deutsch (*The Hebrew University, Jerusalem, Israel*), and H. Tabor, A.Inst.P. (*National Physical Laboratory of Israel, Jerusalem, Israel*).

In order to measure the slope of a curve at a given point, a vertical half-silvered mirror is set perpendicular to the curve by rotating it until the reflection of one half of the curve in the mirror coincides as nearly as possible with the other half of the curve, seen through the mirror. The instrument is fitted with both a tangent scale and a degree scale and, in favourable circumstances, is capable of an accuracy of $\pm 0{\cdot}25°$.

A sensitive electronic strain gauge. By H. L. Allsopp and D. F. Gibbs, A.Inst.P. (*H. H. Wills Physics Laboratory, University of Bristol*).

A sensitive strain gauge which was developed for investigating the electromechanical properties of ferroelectric barium titanate is described. It responds faithfully only to displacements occurring fairly rapidly, i.e., in less than about 1 s. The lower limit of its response time is determined mainly by the mechanical system coupling the specimen to the gauge, and is of the order of 1 ms. The limit of sensitivity is about 10^{-7} cm, but the sensitivity is variable over a wide range and absolute calibration is possible. The design allows the specimen temperature to be controlled over a range —150 to +200°C.

The optimum design of quarter-squares multipliers with segmented characteristics.

By M. E. Fisher (*Wheatstone Physics Laboratory, King's College, London*).

A general discussion of quarter-squares multiplication shows that there are no serious disadvantages in the use of non-linear units with monotonic characteristics. The total truncation error, due to the approximation of the ideal non-linear characteristics by a finite number of equal linear segments, is evaluated. Formulae are deduced for optimizing a multiplier's performance in specified applications by using segments of unequal lengths. In typical cases savings of between 5 and 20% in the number of segments needed for a given accuracy can be achieved : the optimum distributions of segment lengths differ only slightly from the uniform distribution with equal segments.

Two portable thermistor radiometers. By W. H. Ward, B.Sc.(Eng.) (*Rothamsted Experimental Station, Harpenden, Herts*).

The construction and calibration of two portable radiometers, suitable for micrometeorological studies, is described. One instrument measures the hemispherical short-wave radiation and the other measures directly the total radiative flux through a plane. Attachments to the latter instrument permit total hemispherical radiation and psychometric measurements to be made. Small dry batteries, a tiny motor, a simple Wheatstone's bridge and thermistors are used.

A bolometer detector for the measurement of shock velocity in low density gases. By J. G. Clouston, A.Inst.P., L. J. Drummond, and W. F. Hunter (*Department of Supply, Australia*).

In applying the shock tube as a device for the study of chemical kinetics it is necessary to measure the velocity of the shock wave so that the energy input is characterized by the shock strength. A suitable detector of a shock wave, used to determine shock velocities, should have adequate sensitivity in order to detect weak shocks in low density gases and also have a high speed of response to reduce timing errors to a minimum. It should also be robust and resistant to corrosive substances and be able to be placed in the shock tube so that the shock front is not disturbed in passing it. This note describes such a detector.

A projection spectrum comparator. By C. F. Smith (*1 Wood End Close, Farnham Common, Bucks*).

A new instrument for the comparison of spectrograms of 10 in. × 4 in. or other standard sizes, produces images in juxtaposition at a magnification of 20 on a 9 in. × 7 in. translucent screen. There are controls for focusing and for the longitudinal, transverse and radial movements of the spectrum plates, and neutral tint wedges enable the brightness of the images to be equalized. An engraving tool is for the marking of selected spectrum lines, and a photographic attachment is used for the recording of comparison spectra. Wavelengths may be established by interpolation from measurements of known line separations with a micrometer attached to one of the carriages, or by comparison with standard spectrum maps by a beam splitter.

A precision bath thermostat. By W. Wilson, M.B.E., and N. W. B. Stone, A.Inst.P. (*National Physical Laboratory, Teddington, Middlesex*).

A thermostat is described for controlling the temperature of a 30 l. paraffin bath slightly above room temperature to a thousandth of a degree Celsius. An a.c. bridge is used in conjunction with a phase sensitive valve (originally developed as a frequency modulation detector).

An exposure calculator for isotope radiography. By T. A. Cosh (*The British Steel Castings Research Association, Sheffield*).

The factors affecting exposure time in gamma radiography using radon, ^{60}cobalt, ^{192}iridium, ^{170}thulium and ^{137}caesium are correlated so that for any stated conditions the exposure time is rapidly determined. While primarily designed for the radiography of steel the use of thickness conversion scales enables the calculator to be used to determine the exposure time for other materials.

LABORATORY AND WORKSHOP NOTES

NOTES AND NEWS

NEW BOOKS

NOTES AND COMMENTS

British Journal of Applied Physics: Volume 8, No. 8

CONFERENCE REPORT

Summarized proceedings of a conference on stress analysis—Cranfield, September, 1956

The Tenth Annual Conference of the Stress Analysis Group of The Institute of Physics was held at the College of Aeronautics on 19, 20 and 21 September, 1956, in conjunction with the Royal Aeronautical Society. Papers were read which could be divided into four main subjects : kinetic heating, extensometry and instrumentation, jet efflux and crack propagation, and the proceedings are summarized in this report.

A review of recent improvements in methods of experimental stress analysis in the U.S.A. and Canada was given by Mr. A. F. C. Brown.

SPECIAL ARTICLE

On the elementary theory of thermoelectric phenomena. By R. Stratton, A.Inst.P. (*Metropolitan-Vickers Electrical Co. Ltd., Manchester*).

The theory of thermoelectric phenomena is deduced from the general theory of conduction in a metal or semi-conductor. The calculation, which is well known, is discussed in great detail to bring out the significance of the various thermoelectric parameters. All the relations between the thermoelectric parameters are deduced from physical properties rather than by simply carrying out mathematical transformations. The sources of the heat and electromotive force developed are clearly indicated.

ORIGINAL CONTRIBUTIONS

The oxidation of evaporated barium films (getters). By R. N. Bloomer (*Research Laboratory, Associated Electrical Industries Ltd., Aldermaston, Berks*).

Mott's theory of the oxidation of metals is summarized and expressed in terms comparable with the throughput, capacity, and speed of pumping, which are measured in the present work on barium getters.

It has been found that there is a critical temperature, about 40°C for barium, below which a thin protective film of oxide is formed. Above 40°C, barium films oxidize right through, and so in this case, the capacity of getters for oxygen depends upon the amount of metal used. The feature of the mechanism which limits the speed of pumping of oxygen has been found, and hence the speed has been increased in various ways. The theory of Mott concerns only the growth of an oxide film that is already at least a monolayer thick. In the present study it has been found that the first monolayer spreads from nucleation centres in the barium surface.

Measurements of the impedance parameters of junction transistors. By E. E. Ward (*Electrical Engineering Department, University of Birmingham*).

The paper describes with practical details equipment for making null measurements of the earthed-base impedance parameters and of α^1. Measurements on collector open-circuit are included and typical results at frequencies up to 30 kc/s are given.

The emission from oxide cathodes in low pressure discharges. By M. A. Cayless, A.Inst.P. (*The British Thomson-Houston Co., Ltd., Rugby*).

It is shown that measurements made in vacuum on oxide-coated discharge cathodes are unreliable as a measure of the properties of the cathode in the gas atmosphere of the discharge. Several known methods of measuring the zero-field emission of cathodes in gas atmospheres are found to give rise to difficulties when applied to oxide cathodes in several millimetres pressure of rare gas. A method is described in which these difficulties are avoided and it is applied to a study of cathodes of the fluorescent lamp type. It is found that the zero-field emission of these cathodes at operating temperatures is considerably higher than the thermionic emission measured in vacuum, but still much smaller than the discharge current which they normally pass. It is shown that the various secondary and field emission processes must play a prominent part in the normal operation of these cathodes which, in fact, need not necessarily be particularly good thermionic emitters.

The spectral reflectivity of back-surface and front-surface aluminized mirrors. By G. G. Twidle (*Light Division, National Physical Laboratory, Teddington, Middlesex*).

Results are given of a determination of spectral reflectivity of back- and front-aluminized quartz mirrors in the wavelength-range 0·25–1·35 μ. A resumé is given, including reference to other recent work on front-surface mirrors, showing what are thought to be the highest values of reflectivity obtainable over the range 0·1–12 μ. The technical precautions necessary for the attainment of these optimum values are discussed in practical terms.

Determination of the impurity concentrations in a semiconductor from Hall coefficient measurements. By P. A. Lee, A.Inst.P. (*The British Thomson-Houston Co. Ltd., Rugby*).

The equation is derived for the carrier concentration as a function of temperature and the concentrations of the acceptors and donors in a semiconductor. As a result, it is shown how these impurity concentrations may be found experimentally from a determination of the Hall coefficient as a function of the temperature. These methods are applied to the case of *p*-type silicon which is dealt with in some detail.

NOTES AND NEWS

NOTES AND COMMENTS

UNIVERSITY OF KHARTOUM

Applications are invited for the

CHAIR OF PHYSICS

Salary £S 2,400 p.a., cost of living allowance approximately £S 90 p.a., outfit allowance £S 50. Family allowances : wife—£S 60 p.a., 1st child—£S 90 p.a., 2nd and 3rd child—£S 30 p.a. each. Passages for appointee and family on appointment, termination and annual leave. Superannuation scheme. Initial appointment five years with possibility of renewal, though shorter contracts are also possible.

Detailed applications (eight copies) naming three referees by September 30, to Secretary, Inter-University Council for Higher Education Overseas, 29 Woburn Square, London, W.C.1, from whom further particulars may be obtained.

RESEARCH PHYSICAL METALLURGIST

An opportunity occurs for an honours graduate in metallurgy or physics having an interest in research on materials to join a small team in

North Acton

investigating long- and short-term projects aimed at developing the industrial applications of the platinum-group metals. This is an interesting appointment in an unusual field and carries an attractive salary.

Apply to :

The Manager, Development and Research Department
The Mond Nickel Co. Ltd.

Thames House, Millbank, London, S.W.1
Mark envelope confidential, PM4.

X-RAYS

British Nylon Spinners invite applications for a vacancy in their Research Department. The work will involve the application of X-ray techniques, including low angle scattering and counter diffractometry, to structural and textural studies of polyamides, and to the investigation of the spinning and drawing processes of polymer fibres.

Candidates should have first- or second-class honours in physics (preferably) or chemistry, and both experience in X-ray diffraction work, and of work with polymers are desirable.

A good starting salary will be paid. There are opportunities for further progress, and conditions of service are excellent. Applications should be addressed to : Personnel Manager, British Nylon Spinners Ltd., Pontypool, Mon.

HONOURS GRADUATE required for theoretical work on the distribution, evaporation and combustion of liquid fuels in diesel engines. Experience in one or more of the following would be an advantage : heat and mass transfer, thermodynamics, computer programming. Write stating age, qualifications and experience to the Personnel Manager, C.A.V. Ltd., Warple Way, Acton, W.3, Ref. R.32.

JOSEPH LUCAS (ELECTRICAL) LTD.

Great King Street, Birmingham

As a result of expansion of our road vehicle lighting development department to meet the growing demands of the motor industry we have vacancies for engineers and physicists of at least H.N.C. standard to work on the following projects. Experience or knowledge of photometric and electrical instruments desirable.

The design and development of vehicle lighting equipment and in particular the development of optical systems for future projects.

Development work on specific problems related to vehicle lighting equipment and the design of laboratory and factory control equipment for these products.

In addition there are vacancies for senior designers required to work in close co-operation with car designers and styling engineers on the design of lighting equipment for new car models. Experience in the design of pressed metal components for large quantity production desirable.

All these positions carry attractive starting salaries and provide excellent prospects for advancement. Staff Pension Fund.

Apply in writing stating age, qualifications and experience to the Personnel Manager, Joseph Lucas (Electrical) Ltd., Great King Street, Birmingham, 19, quoting reference PM/D/156.

BASIC IRRADIATION STUDIES GROUP

A.E.R.E., Harwell

Vacancies exist for Scientific Officers, Experimental Officers and Assistants (Scientific), to work as members of small teams studying the effects of irradiation on the properties of materials required for the Nuclear Power Programme.

The positions afford excellent opportunities to obtain experience in a new and expanding field. The work is of a non-routine nature and should appeal to those with a flair for experimental techniques.

In the case of the junior grades there are facilities for further education.

Minimum qualifications :

Scientific Officer Class : Good Honours degree.
Experimental Officer Class : G.C.E. in five subjects, including two mathematical or scientific subjects at 'A' level.
Assistant (Scientific) Class : G.C.E. (O) in four subjects including English Language and Mathematics or Science.

Salaries :

Scientific Officer Class : £610 – £1,355.
Experimental Officer Class : £375 – £1,550.
Assistant (Scientific) Class : £305 – £965.

Housing, superannuation and other excellent working conditions.

Send postcard by August 25, 1957, for further details and an application form to Group Recruitment Officer (850z/110), A.E.R.E., Harwell, Didcot, Berks.

Chartered Patent Agents

W. H. BECK, GREENER & CO.

7 Stone Buildings,
Lincoln's Inn,
London, W.C.2
Chancery 2535

PHYSICISTS

British Enka Ltd., producers of man-made fibres, require Physicists in their Research Department, based on newly-constructed, well-equipped laboratories. Applicants should have good honours or research degrees and will be required to deal with experimental problems in the field of classical physics. These posts offer permanent employment with progressive opportunities, good salaries and pension scheme for suitable applicants. Applications in strict confidence should state age, qualifications, experience in chronological order, and be addressed to Personnel Manager, British Enka Ltd., Aintree, Liverpool, 9.

THE LONDON HOSPITAL

WHITECHAPEL, E.1

Basic grade Physicist required in physics laboratory. Hospital physics experience desirable, but not essential. The post provides good all-round experience of radiotherapy physics, including the clinical applications of a kilocurie cobalt unit. There is also an opportunity to collaborate in development and research work. Whitley Council salary scale. If successful applicant is a woman, accommodation is available, if required, at Hotel in Kensington run by the hospital for the benefit of its women staff and students. Applications, with names of two referees, to House Governor by August 17.

PHYSICISTS

required by

The Atomic Weapons Research Establishment, Aldermaston, Berks, in the grade of Experimental Officer/Assistant Experimental Officer to work in collaboration with scientists on research in the following :

(*a*) properties of solids under high stress and high rates of strain ;
(*b*) physics of detonation process and propagation of intense shock waves ;
(*c*) development of transient spectographic techniques and application to study of high temperature gas shocks ;
(*d*) experimental hydromagnetics.

The work comprises both applied and basic problems in an interesting specialized field requiring unusual experimental facilities which are well provided.

Minimum qualification is H.S.C.(Science) or equivalent but candidates for Experimental Officer posts should be at least 26 years of age and preferably possess an ordinary degree (physics). A sound basis of classical physics required, especially in optics and the properties of materials. Experience in electronic recording techniques desirable but not essential.

Salary : Experimental Officer £940 - £1,155 (male)
Assistant Experimental Officer £375 (age 18) - £665 (age 26 or over) - £815 (male).

Contributory superannuation scheme.

A house or assistance towards legal expenses on house purchase will be available for married officers living beyond daily travelling distance.

Postcards for application forms to Senior Recruitment Officer at above address. Please quote ref. A/1463/110.

A vacancy exists for someone with experience of specimen preparation for electron microscopy and operation of the electron microscope. Interesting and varied work. Excellent working conditions in pleasant district. Good salary. Superannuation scheme.

Apply to : Aeon Laboratories, Beech Hill, Ridgemead Road, Englefield Green, Egham, Surrey.

PHYSICISTS
IMPERIAL CHEMICAL INDUSTRIES LIMITED

Dyestuffs Division
require
PHYSICISTS
to work in their
Research Department in
MANCHESTER

Physics is playing an increasingly important part in the Chemical Industry and there are openings for physicists who wish to do fundamental research as well as for those whose interests lie in applied research. There are opportunities for physicists without specialist qualifications as well as those who have already specialized, provided that they hold good honours degrees. Encouragement will be given to successful applicants to become specialists in one of the several fields and techniques currently being studied and to suggest further work in their own and allied fields.

The Company operates pension and profit-sharing schemes, pays good salaries and provides modern and well-equipped laboratory accommodation. After joining the staff, married men receive a reasonable refund of removal expenses and to assist them in house purchase, facilities are available in approved cases for loans.

Those interested in learning at first hand of the rewarding careers which can be offered in an expanding physics team are invited to write to the Staff Department, Hexagon House, Blackley, Manchester, 9, quoting reference I/28, and giving brief details of age, qualifications and experience.

BRITISH PETROLEUM CO. LTD. has vacancies for Geophysicists on its exploration staff. Candidates should have an honours degree in physics with subsidiary mathematics and/or geology. Basic salary is commensurate with age and experience, commencing at £1,075 for young inexperienced graduates. Appropriate allowances are paid on foreign service. Generous pension scheme. Written applications, quoting reference F.533 should be addressed to Personnel Manager, British Petroleum Co. Ltd., Britannic House, Finsbury Circus, London, E.C.2.

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Appointments Vacant

The inclusion of particulars of a vacancy must not be taken to imply that the Institute necessarily approves of the terms offered or that might be offered. Candidates should satisfy themselves that these are satisfactory, and they may always refer to the Institute for advice.

SCIENTIFIC OFFICERS

required by

THE ATOMIC WEAPONS RESEARCH ESTABLISHMENT,
FOULNESS, ESSEX

For the development and application of instrumentation for research on explosives and properties of materials under conditions of high pressures and temperatures, with opportunities for original design work in the solution of unusual problems.

First or second class honours degree in appropriate science subjects, or equivalent qualifications required and preferably some knowledge of electronics.

Salary : To be assessed according to age, qualifications and experience within the scale £610–£1,065 p.a. (male).

Contributory superannuation scheme. A house or assistance towards legal expenses on house purchase will be available for married officers living beyond daily travelling distance.

Postcards for application forms to the Senior Recruitment Officer at A.W.R.E., Aldermaston, Berks. Please quote ref. 1563/110.

BRITISH THOMSON-HOUSTON CO. LTD.

The British Thomson-Houston Co. Ltd. has vacancies in an expanding research group working on problems associated with the applications of semiconducting materials. There are vacancies for physicists with good honours degrees, technicians with H.N.C. or G.C.E. A level and a mathematical physicist. The successful applicant for the latter post would be concerned with the analysis of data and also the application of theoretical physics to the search for new semiconducting materials and devices.

The positions are pensionable and offer excellent prospects.

Applicants are invited to write to the Director of Research, The British Thomson-Houston Co. Ltd., Rugby, stating age, qualifications and experience and quoting reference W.1.

Vacancies exist for Physicists, Engineers and Chemists with degrees or equivalent qualifications, in the Industrial and Domestic Division of the British Coal Utilization Research Association for urgent projects relating to gasification, pyrolysis reactions, specialized instrument mechanisms, the design of grate and feed mechanisms, etc. Applicants, who should possess general adaptability, will be encouraged to publish the results of their work, and are given every opportunity of meeting the technical representatives of the industries concerned.

Salaries according to qualifications and experience, but in the range £700–£1,000 for younger men.

Five day week, superannuation and grading schemes. Apply in writing to Assistant Secretary, Ref. I.D., B.C.U.R.A., Randalls Road, Leatherhead, Surrey.

UNIVERSITY OF THE WITWATERSRAND

JOHANNESBURG, SOUTH AFRICA

(*a*) Lecturer in Mathematics
(*b*) Lecturer in Mathematical Statistics.

Applications are invited for appointment to two posts of Lecturer on the staff of the Department of Mathematics. Special qualifications in, and the ability to lecture in Mathematical Statistics, are essential in the case of (*b*).

Duties are to be assumed on February 1, 1958, or as soon as possible thereafter. The salary attached to the post of lecturer is on the scale £850 × £50–£1,200 per annum, plus a temporary cost of living allowance, at present at the rate of £234 per annum, in the case of a married man. The initial salary will be determined by experience and qualifications.

Membership of the University Institutions Provident Fund is compulsory. Membership of the Staff Medical Aid Fund is compulsory in the case of an officer who is eligible for membership.

Applicants are advised to obtain a copy of the informa- sheet relating to this vacancy from the Secretary, Association of Universities of the British Commonwealth, 36 Gordon Square, London, W.C.1.

Applications close in South Africa and London, on September 30, 1957.

SOLID STATE PHYSICS. Physicists, Engineers and Metallurgists are required by Mullard Research Laboratories for fundamental research on the growing of crystals, the study of electrical, optical and surface properties of semiconductors and on the investigation of new and advanced semiconductor devices. Previous experience in this field will be an advantage, but is not necessary. Recent graduates are invited to apply. Salaries fully commensurate with experience and in line with present trends will be offered to suitable applicants. These posts come within the Company's Life Assurance and Superannuation schemes. Apply in writing to Mr. G. A. Taylor, Personnel Officer, Mullard Research Laboratories, Cross Oak Lane, Salfords, Redhill, Surrey. Order No. 355.

BRITISH PETROLEUM CO. LTD., have a vacancy in the geophysical section of their Research Station, for a Physicist with an honours degree and at least two years' research experience. Some knowledge and experience of high-voltage pulse techniques is very desirable. Whilst direct experience in applied geophysics is not essential, it would be considered an advantage. The candidate should be a versatile physicist with a sound fundamental knowledge, capable of working on a variety of problems which arise in connection with various methods of geophysical surveying. Excellent working conditions. Non-contributory pension scheme. Write giving full details, quoting H.3597 to The Manager, Recruitment Branch, The British Petroleum Co. Ltd., Britannic House, Finsbury Circus, London, E.C.2.

AUCKLAND UNIVERSITY COLLEGE
(University of New Zealand)

The College Council invites applications for a vacant Lectureship in Physics.

The salary scale for a Lecturer is £1,025–£1,275 per annum, by three annual increments. Commencing salary within this scale will be fixed according to qualifications and experience. An allowance is made towards travelling expenses.

Further particulars and information as to the method of application may be obtained from the Secretary, Association of Universities of the British Commonwealth, 36 Gordon Square, London, W.C.1.

The closing date for the receipt of applications, in New Zealand and London is September 20, 1957.

NEW SOUTH WALES UNIVERSITY OF TECHNOLOGY
Sydney, Australia

Vacancy for Associate Professor of Physics
School of Applied Physics

The University invites applications for appointment to the position of Associate Professor in Physics which will become vacant on January 1, 1958. Salary £A2,415 per annum. Applicants must possess a higher degree in physics and submit evidence of extensive original work. Research record (academic or industrial) and teaching experience will be considered as important. The Associate Professor will be required to act as deputy to the Head of the School, and to supervise the teaching work of the school. He will be expected to lecture in selected branches of physics to advanced undergraduate classes, and will have opportunity to develop postgraduate classes and to carry out and to direct research. Experimental facilities exist for X-ray, optical, vacuum and magnetic studies and the School is adjacent to the University's high-speed digital computer. Further particulars may be obtained from the Head of the School of Applied Physics, Kensington, New South Wales.

Successful applicant will be eligible, subject to medical fitness, to contribute to the State Superannuation Fund, for a pension of £A1,270 per annum. Professors are eligible for six months' study leave on full salary after three years of service or twelve months after six years of service. The University reserves the right to fill the position by invitation.

First class shipping fares to Sydney of successful applicant and his family will be paid.

Five copies of applications (including the names of two referees) should be lodged with the Agent General for New South Wales, 56/57 Strand, London, W.C.2, and a copy forwarded in an envelope marked "University Appointment" by Airmail to the Bursar, Box 1, Post Office, Kensington, New South Wales, Australia, by October 1, 1957.

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Department of Physics

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Details and application forms may be obtained from :

The Secretary,
Physics Department,
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